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DECEMBER 1954

School Science and Mathematics

A Journal for All Science and Mathematics Teachers

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"I have always thought of Christmas as a good time; a kind, forgiving, charitable, pleasant time; the only time I know of in the long calendar of the year when men and women seem, by one consent, to open their shut-up hearts freely."—CHARLES DICKENS.

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School Science and Mathematics

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Is read by subscribers in every state of the Union, all provinces of Canada, and thirty-three foreign countries.
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SCHOOL SCIENCE
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MATHEMATICS

VOL. LIV DECEMBER, 1954 WHOLE NO. 479

POSTAGE STAMP SCIENCE*

JAMES K. ANTHONY
Southern University, Baton Rouge, Louisiana

Practically all phases of science—both biological and natural—have been represented on postage stamps of the world and attractive mounts can be made by the teacher or by the class as a project. A wealth of bird pictures may be displayed on stamps from the following countries: Guatemala, *quetzal;* Italian East Africa, *falcon;* New Guinea, *Bird of Paradise;* Borneo, *cockatoo;* Cayman Islands, *booby gannets;* and Falkland Islands, *king penguin, Gentoo penguin, upland geese* and *black-neck swan.* This is by no means all of the birds that adorn postage stamps, for the interested teacher will find *frigate birds, hornbills, guano gannets, toucans, kookaburras, kiwis, lyrebirds, emus, condors,* and *ostriches* as well as a set of triangular-shaped stamps from Hungary of their native birds.

In 1953 Hungary issued a set of multicolored stamps portraying animals of the woods such as deer, hares, weasels, and squirrels to name a few. However, most of the tropical countries have given philatetic cognizance to the assorted animal life which abounds within their boundaries. Australia and New Zealand have shown the *kangaroos, koala bears, Merino sheep, duckbill platypus,* and *tautara lizards;* Ecudaor, *Galapagos turtles* and *iguanas;* Bolivia, *llamas, vicunas, chinchillas,* and *jaguars:* Belgian Congo, *screwhorn antelopes, chimpanzees,* and *crocodiles;* Borneo, *Malay tapir, wild boar,* and *proboscis monkeys;* and Belgian East Africa has shown the *okapi* and *leopard.* In 1935 Tanna Tuva, which lies between Outer Mongolia and

* This is the second of a series of articles showing how postage stamps may be used to supplement classroom teaching. The other is; "Postage Stamps as Visual Aid Material in the Teaching of Geography," *Journal of Geography,* vol. 47 (1948) 325–328.

the Siberian regions of the Soviet Union, issued a set of 10 varieties of zoological subjects and they are ranked as some of the most beautiful and interesting stamps that have been released by any country.

Ichthyology is represented with the *codfish* and *salmon* on Newfoundland stamps; *herring* on Iceland; and *marlin swordfish* on New Zealand. Mozambique has issued a colorful set of stamps of insects and Lebanon has shown a *silkworm*, *cocoon*, and *moth*.

The botanist might be interested to know that flowers and trees have been well represented on stamps. Honduras, *sugar cane*, *orchids*, and *wheat;* Labuan, *sago palm*; Toga, *breadfruit trees;* British Honduras, *mahogany trees*, *cohune palms*, and *grapes;* Gilbert and Ellice, *pandanus* and *coconut trees;* Israel, *Rose of Sharon*, *figs*, and *nuts;* and South West Africa, *welwitschia plant*. In addition there are many scenes of economic activities shown involving the use of plants, for example, the gathering of chicle and latex; the harvesting of wheat; and natives climbing trees for coconuts.

Astronomy has not been ignored. In 1942 the Mexican government issued a set of stamps commemorating the opening of its new national observatory. The scenes are the spiral galaxy (*N.G.C. 4594*), the horsehead nebula in Orion, the spiral galaxy in Canes Venatici, the planetary nebula in Lyra, and an eclipse of the sun. In 1948 the United States Post office issued a stamp showing the Palomar Observatory and Italy has placed a picture of Galileo on one of its stamps.

Geology is represented particularly on stamps from countries that have famous mountains within their bounaries. Some outstanding volcanoes of the unstable margins of the Pacific Ocean can be listed: Bolivia, *Mts. Potosi* and *Illimani;* Ecuador, *Mt. Chimborazo;* Guatemala, *Mt. Agua;* Mexico, *Mts. Orizaba* and *Popocatepetl;* Nicaragua, *Mt. Momotombo;* San Salvador, *Mts. Izalco* and *San Miguel;* United States, *Crater Lake;* Japan, *Mts. Fujiyama*, *Nantai*, *Hiuchidake*, *Daisen*, *Nakadake*, and *Aso* the latter which erupted early in 1953 killing several school children who were on a field trip near its crater. Iceland has portrayed the active *Mt. Heckla* and the extinct *Snaefellsjokull*.

Finally, the men who make scientific headlines by their discoveries and inventions have found prominent places on stamps of many countries. During the year 1940 the United States issued two series of stamps honoring scientists and inventors. The former series included John James Audubon, Dr. Crawford Long, Luther Burbank, and Dr. Walter Reed; the latter included Eli Whitney, Samuel F. B. Morse, Cyrus Hall McCormick, Elias Howe, and Alexander Graham Bell. In 1948 Hungary honored Johannes Gutenberg, Robert Fulton, George Stephenson, Thomas A. Edison, Ferdinand von Zeppelin and Louis Bleriot.

HOLIDAY GREETINGS FROM THIRTY SCRAMBLED MATHEMATICIANS

C. W. TRIGG
Los Angeles City College

Rearrange the letters of each of the following numbered words or phrases in order to unscramble the name of each mathematician and thus read the holiday message formed by the initial letters of the names.

(1) LIFT A MAT
(2) AS ON THE TREES
(3) NOR HASP
(4) OR ELL
(5) NO GUY
(6) CLASS, EH?
(7) ROT HAIR
(8) MA, JUAN RAN
(9) I CLAIM BUSH
(10) LEVY RESTS
(11) HAS LET
(12) MY ROLE
(13) A SAX, A GROAN
(14) STRUM
(15) I STOLE TAR
(16) WON TEN
(17) ODD SONG
(18) SEA GIN
(19) NOR HE
(20) CAR HIDES ME
(21) TOM PYLE
(22) REPLUCK
(23) A RAG IN A HAY
(24) SEND, I COME
(25) IL DUCE
(26) I RENEW
(27) I HUG ANY
(28) I SEE IN NEST
(29) AH! A BAY RAT
(30) SELL U. S. R.

(The unscrambled names and the message appear on page 694.)

PROFESSOR WILLIAMS RECEIVES KENDALL AWARD

J. W. Williams, professor of chemistry at the University of Wisconsin, was named as the 1954 recipient of the $1,000 Kendall Award of the American Chemical Society for his research contributions to the field of colloid chemistry.

The announcement was made at the national meeting of the chemical society in New York. Prof. Williams is the second scientist to receive the Kendall Award since its establishment.

Prof. Williams was among the first chemists to apply the exact techniques of physical chemistry, especially those utilizing electrical measuring instruments and the ultracentrifuge, to research on problems of colloid chemistry. He is especially well-known for his work in the field of protein chemistry and blood substitutes.

Prof. Williams received both his master's and doctorate degrees from the University of Wisconsin, the first in 1922 and the latter in 1925. He has been a full professor since 1938. In addition to his teaching and research at Wisconsin he studied at Copenhagen and Leipzig in 1927 on a National Research Council fellowship, at the University of Upsala, Sweden, in 1934, on an International Education Board Fellowship, and he served as visiting professor during 1946 at the California Institute of Technology.

AN ENDLESS THREAD

A. N. TUCKER
J. Sterling Morton Junior College, Cicero, Illinois

At Christmas time, we single out the words "Peace on Earth, Good Will to Men" as having special significance. Yet to bring about this goal, the idea must be woven with an endless thread through out all we do, every hour, every day, every month.

SCIENTIFIC PAPERS OF MARIA SKLODOWSKA-CURIE TO BE PUBLISHED

The Polish Academy of Sciences has announced the forthcoming publication of the complete original texts of the scientific papers of Maria Sklodowska-Curie, the great Polish scientist who with her French husband, Pierre, discovered radium in 1898. The papers are to be issued as part of Poland's nation-wide commemoration this year of the twentieth anniversary of Mme. Sklodowska-Curie's death.

An introduction has been written by the scientist's daughter, Irene Joliot-Curie, an outstanding physicist.

SCIENCE PHOTOGRAPHY AIDS VISUAL AIDS PROGRAM

HAROLD HAINFELD
Roosevelt School, Union City, N.J.

Science teachers are frequently called upon to assist in the school audio-visual program. Because of mechanical ability and knowledge of electricity, sound and light, the science teacher is often in charge of the school projector and the student projection squad. While not necessarily responsible for the requisitioning of the films that are shown as part of the audio-visual program, he is usually called upon to train the student operators of the motion picture equipment.

With an interest in photography, the science teacher can aid in evaluating student interest in the film materials being shown. It is possible to photograph your pupils watching educational motion pictures without their knowing it.

One method is to use infra-red photography which was developed to a large extent by the Air Force for camouflage detection during World War II. The infra-red film is used instead of the familiar pancromatic type. This film is sensitive to the invisible infra-red rays. A No. 22 infra-red "flash" bulb is used. This bulb resembles the regular flash bulb used in photography, except that it is coated with a purple-black lacquer that permits only the invisible infra-red rays to go over the area. The bulb flashes, as would the regular bulb, but nothing is seen by the audience.

In our experiments at Roosevelt School an Argus C-3, 35 mm. camera was used. A lens opening of f 3.5 and shutter speed of 1/50th second were the settings used on the camera. With the infra-red film, focus is not the same as with regular pancromatic film. An area 20 feet from the camera can be photographed with the infra-red film and bulb, however, due to the short rays a distance of 25 feet must be set on the camera to have the pictures come out in focus.

Large camera stores will usually have a small stock of infra-red film and bulbs or will be glad to get some for you. Cost of film and bulbs is slightly more than regular 35 mm. film and the regular flash bulbs.

Another possibility of observing the effectiveness of the visual aids program is to use time-lapse photography. In this case the familiar Super-XX fast film is used. The reflected light from the screen is used as the source of light. We used a lens opening of f 5.6 and a time exposure of 2 seconds. After the lights in the room were turned off, and the projector started, the camera, mounted on a tripod was placed on the table next to the screen and the speaker. It is usually not

satisfactory to take pictures at greater than 1/25th second with the camera being held in the hand. The camera on the tripod gives a much steadier picture. A cable release is used to take the picture. At 1/50th second and infra-red film, action is stopped. Student expression can be studied and their interest in the film noted. It might be pointed out that it is possible to take the picture with a flash bulb and regular pancromatic film and get an excellent shot. With the flash bulb a much clearer picture will result. However, after one picture is taken, the student is blinded by the flash. Interest is distracted from the film being shown to the photographer. With the time-lapse photography, interest can also be studied with student interest being observed on the print of the picture taken.

Evaluation of teaching materials is an important phase of utilization. It is very difficult to observe student reactions to films being shown when they are viewed in the darkened room. You, too, may find that when films are well selected, student interest is keen. The use of infra-red and/or time photography will enable the science teacher to aid those responsible for the use of visual materials to evaluate their offerings more fully.

WOMEN ASSUME NEW INDUSTRIAL ROLE, SAYS WESTINGHOUSE ENGINEER

The engineering profession no longer is limited to the masculine sex as women are becoming more and more generally accepted in this field, Miss Emma Barth, an engineer for Westinghouse Electric Corporation, asserted.

Miss Barth who earned her engineering degree after seven years of studies at the University of Pittsburgh evening school and who now is working on mechanical designs for turbine generators at the Westinghouse East Pittsburgh plant, was the principal speaker at a meeting of the Dixie Engineering Association.

"Unfortunately," Miss Barth said, "the general public still thinks of the word 'engineer' as masculine. Qualifications for engineering include a liking of science, an aptitude for mathematics, an interest in science and the ability to visualize, none of which is directly correlated with sex.

"I hope that within a few years a young women entering our profession will only rarely be asked, 'Why did you choose engineering?' It will be taken for granted that she chose engineering from the large number of careers open to her because she liked it better than, for example, bookkeeping, hairdressing, teaching or newspaper reporting."

Miss Barth, a veteran of 10 years service with Westinghouse, cited for her audience other women in the field of engineering and outlined their accomplishments. In this connection she pointed out that a survey at the start of 1953 of 500 engineering firms disclosed that almost half of the companies had used women engineers at one time or another. In this same group, 65 per cent of the firms indicated they were willing to continue hiring women engineers.

As a concluding remark, the Westinghouse engineer commented:

"Although women engineers have occasionally been quoted as saying to other women, 'Come on in; the water's fine,' we are nevertheless careful to extend the invitation to good swimmers only. We don't encourage girls who are looking primarily for glamour and excitement. Engineering isn't that sort of profession."

GEOMETRY OF PAPER FOLDING

II. TETRAHEDRAL MODELS*

C. W. TRIGG

Los Angeles City College, Los Angeles, Calif.

When the surface of a tetrahedron is cut along three correctly chosen edges it can be unfolded into a plane pattern composed of four connected triangles. Now four congruent equilateral triangles can be arranged in a plane edge-connected configuration in only three ways —those shown in Figure 1.

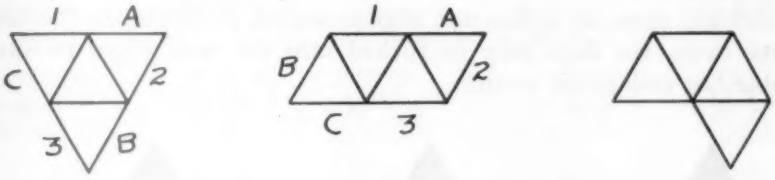


FIG. 1

The first of these configurations results from cutting all the edges which issue from one vertex of a regular tetrahedron. Thus when the surface is unfolded into a plane, an *equilateral triangular pattern* with creases joining the midpoints of the sides is obtained. This is the pattern given in most solid geometry text-books. Its first use is attributed to Dürer by Coolidge.[1]

The second of the configurations results from any continuous three-edge cut which does not complete the circuit of a face. When the surface is unfolded into a plane, a *parallelogram pattern* is obtained.

The third pattern cannot be folded into a tetrahedron, since it has four triangles at a point, whereas the tetrahedron has only three faces at a vertex.

Collapsible Patterns with Closed Edges. A model is usually completed from a plane cardboard pattern by folding and then sealing the open edges with some type of adhesive tape. (An open edge is one through which there is straight line access to the centroid of the solid figure.) Or, a flap attached to one face next to the open edge may be glued to the other face next to the open edge.

The flaps closing the open edges may be made in the shape of equilateral triangles congruent to the faces. Since three edges are cut, three flap triangles will be necessary to close the edges, thus forming a seven-triangle configuration. Designate the pairs of line segments

* This is one of a series of articles contributed at the special request of the editors—G.W.W.

[1] Coolidge, Julian Lowell, *The Mathematics of Great Amateurs*, Oxford University Press, 1950, page 68.

formed by the cuts as A, 1; B, 2; and C, 3, as in Figure 1. The three closing triangles may be attached to each four-triangle pattern in 2^3 ways, namely to: 123, 12C, 1B3, A23, AB3, A2C, 1BC, and ABC. Now if rotations and reflections of a configuration are not considered as distinct configurations, the 16 patterns reduce to 4 distinct seven-triangle patterns which can be folded into regular tetrahedra with no open edges.[2]

These patterns are shown in Figure 2, wherein the black triangles are the closing flaps. The three patterns in the first row of the figure are distinct. The patterns in the second row have the same configuration in which the closing flaps form three different sub-sets. In each of the last three cases, the flaps close two edges on one face, so the model will open up unless one edge is sealed. However, in the first three cases, the flaps may be tucked into the open edges to form stable but collapsible models.

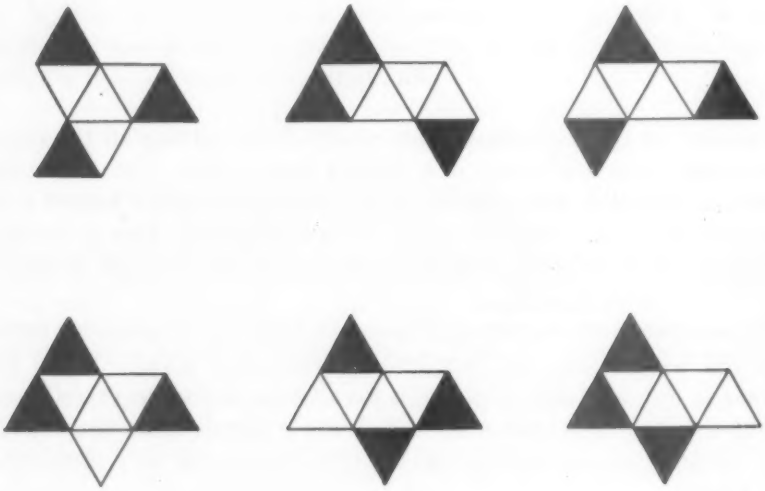


FIG. 2

Patterns for the self-stabilizing models can be drawn easily with compasses and straight edge on paper or light flexible cardboard. Satisfactory models up to 3″ on edge can be made from $8\frac{1}{2}'' \times 11''$ sheets of paper. After collapsing, these can be folded into seven superposed triangles and stowed away in the protractor pocket of a book. Larger models preferably are made from light flexible cardboard (such as in ordinary filing folders) which can be folded more easily and precisely after the uncut edges are lightly scored with the metal

[2] Trigg, C. W. "Folding Tetrahedra," *The American Mathematical Monthly*, 58, pp. 39–40. January, 1951.

end of the compasses. Also, to compensate for the thickness of the cardboard, the vertex angles of the flaps should be made slightly more than 60°.

Collapsible Patterns with One Open Edge. There are twenty other configurations of seven edge-connected equilateral triangles, as shown in Figure 3. All of these except the last one can be folded into regular tetrahedra with one open edge.

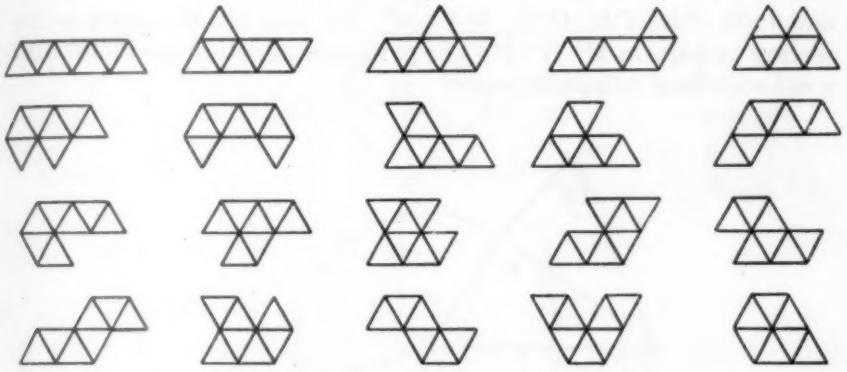


FIG. 3

Patterns for Non-regular Tetrahedra. Lest the student gain the impression that all tetrahedra are regular, it will be instructive for him to prepare a pattern of the surface of an equifacial or isosceles tetrahedron wherein the opposite edges are equal. Thus starting with any acute triangle, MNP, and proceeding clockwise around the triangle each side is produced by an amount equal to its own length. Then parallelograms are completed on the sides as in Figure 4. The model

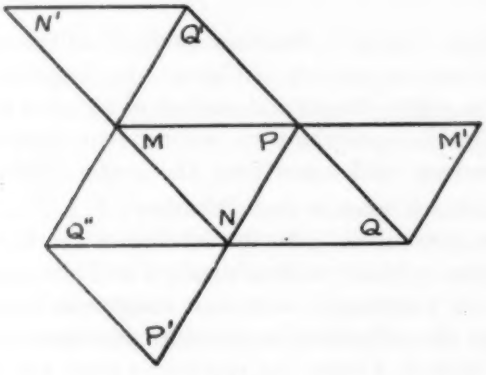


FIG. 4

formed from the pattern is self-stabilizing and collapsible. This is equivalent to folding any acute triangle, $QQ'Q''$, into an isosceles tetrahedron.

By a slight modification of this procedure a pattern for the model of the general tetrahedron $Q-MNP$ can be made. With the vertices M, N, P of triangle MNP as centers and radii MQ, NQ, PQ, respectively, circles are described intersecting by twos outside the triangle in Q, Q', Q'' as in Figure 5. Then with Q, P, Q', M, Q'', N as centers and radii $Q'M$, PM, $Q''N$, MN, QP, NP arcs are described intersecting by pairs in M', N', P'. The pattern thus determined folds into a self-stabilized collapsible model.

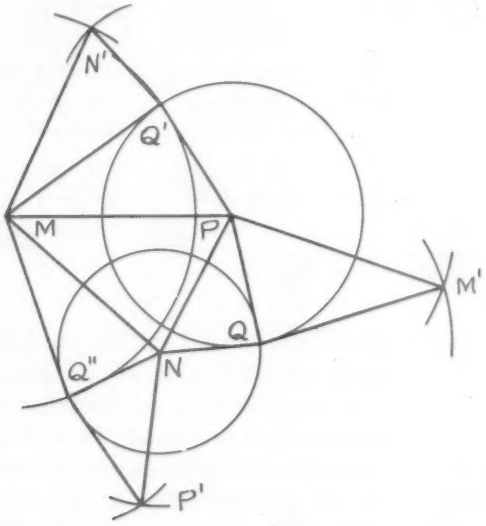
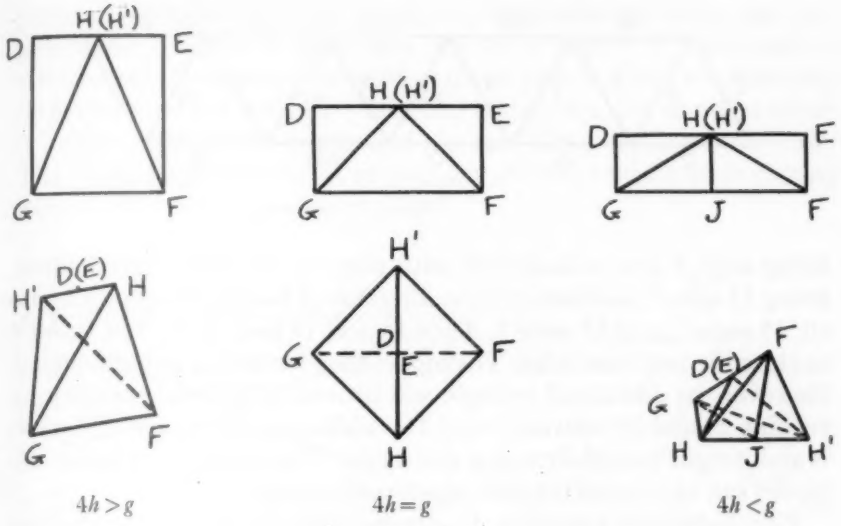


FIG. 5

Tetrahedra from Lateral Cylindrical Surfaces. If the segments 2 and B in the parallelogram pattern of Figure 1 be joined without folding along any of the edges, the lateral surface of a right circular cylinder is obtained. This is equivalent to cutting two opposite edges of a regular tetrahedron and smoothing the surface into a cylindrical surface with circumference $2e$ and altitude $e\sqrt{3/2}$.

This may be generalized into the folding of the lateral surface of any right circular cylinder, with altitude h and circumference g, into a tetrahedron—a bisphenoid with four congruent isosceles triangles as faces. Flatten the cylindrical surface into two superposed rectangles $DEFG$ as in Figure 6. Crease the rectangles from the midpoint H of one open edge, DE, to each of the two opposite vertices, G and F. Hold the open edge GF closed. Separate the open edge DE and bring



$4h>g$ $4h=g$ $4h<g$

FIG. 6

D and E into coincidence by folding along the creases, thus forming the tetrahedron.

If $4h>g$, the tetrahedron will have four edges (the creases) of length $\sqrt{h^2+(g/4)^2}$ and two edges of length $g/2$. Now the volume of an isosceles tetrahedron with edges a, b, c is given by $72V^2=(a^2+b^2-c^2)(b^2+c^2-a^2)(c^2+a^2-b^2)$.[3] So the volume of the tetrahedron is $(g^2/96)\sqrt{16h^2-g^2}$.

If $4h=g$ (the exceptional case), $V=0$. That is, the cylinder flattens into two superposed squares.

If $4h<g$, it will be necessary to make another crease, HJ, perpendicular to DE. The edge DE is opened until HJH' becomes a straight line. The surface is then folded around HJH' until D and E coincide. The tetrahedron thus formed has four edges of length $\sqrt{h^2+(g/4)^2}$, two edges of length $2h$, and volume $(h^2/6)\sqrt{g^2-16h^2}$.

Tetrahedron from Tape. A strip of four equilateral triangles (the parallelogram pattern) folds into a tetrahedron with three open edges. Addition of a fifth triangle to the strip will close one of the open edges. If the folding be continued in the same direction, any number of additional triangles in the strip will fail to close any more edges, since in this case the folding consists essentially of wrapping the strip around a cylindrical surface. However, if a strip of nine triangles, as in Figure 7, be taken after creasing, all edges may be closed by folding as follows:

[3] Altshiller-Court, Nathan, *Modern Pure Solid Geometry*, Macmillan (1935), p. 102; Rosenbaum, J. and Vatriquant, Simon. "Problem E 29," *The American Mathematical Monthly*, 40, pp. 493–4, October, 1933.

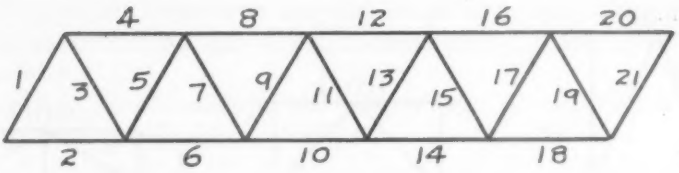


FIG. 7

Bring edge 1 into coincidence with edge 9, forming a tetrahedron. Bring 11 onto 3 and then reverse direction of folding bringing 13 onto 10, 15 onto 7, and 17 onto 8. Then 18 and 19 may be tucked under 4 to close the last open edge. The model thus formed in self-stabilizing. However, an additional triangle will provide additional stability by tucking 20 and 21 between 3 and 11. Adding-machine tape, $2\frac{1}{4}''$ wide, is about right for constructing this model. The model upon being collapsed can be compacted into superposed triangles.

Tetrahedra from Envelopes. If only one edge of a regular tetrahedron is cut, the surface flattens into an envelope open at one end. Indeed this property provides an easy way to construct a sturdy model. Starting with a manila cash (or pay-roll) envelope, as in Figure 8, construct an equilateral triangle *GFH* on the closed end *GF*. Through

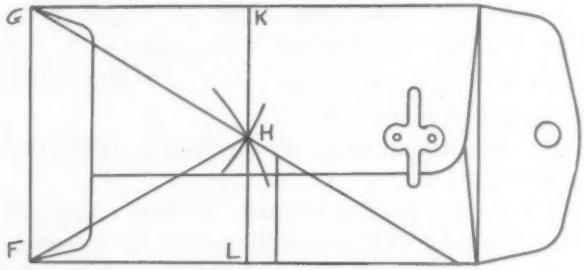


FIG. 8

H draw *KL* perpendicular to the long side of the envelope. Score the pattern with scissors on both sides of the envelope and cut along *KL*. Squeezing in on *GK* and *FL* brings *K* and *L* into coincidence and forms the tetrahedron. The open edge can be taped, or a small flap could have been left on *HL* for pasting. Had the cut been made along *KH* and *GH* extended, a triangular flap would have been formed which could have been tucked in after folding to give a self-stabilized tetrahedron.

Clearly any sealed rectangular envelope when slit along one edge will, depending upon its relative dimensions, duplicate one of the foldings of the lateral surface of a right circular cylinder.

A more spectacular performance with a sealed rectangular envelope

proceeds as follows: Crease along the diagonals and along the perpendicular bisector of the longer side as in Figure 9. Then make a straight cut through the centroid of the rectangle. The two parts may be folded into two congruent isosceles tetrahedra, the shape of which is independent of the direction of the cut. The proof is not difficult.[4] The single exception is that of a square envelope which after cutting flattens into two square envelopes.

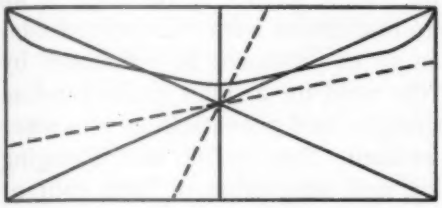


FIG. 9

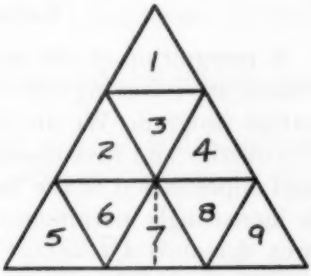


FIG. 10

Equilateral Triangle into Tetrahedron with Closed Edges. The four-triangle configuration of Figure 1 can be folded into a tetrahedron with three open edges. The nine-triangle configuration of Figure 10 can be folded into a regular tetrahedron with no open edges as follows: Crease along the lines separating the triangles and along the altitude of 7. Indicate the side common to two triangles by the numbers of those triangles. Fold up along the altitude and down along 67 and 78. Fold 7 against 6. Bring 3 and 4 into coincidence by folding down along 34. Bring 3 and 2 into coincidence by folding up along 23. Fold up along 13 and down along 56 and 89. This completes the tetrahedron whose faces are 4, 6, 8 and 9.[5]

[4] Trigg, C. W. "Folding an Envelope into Tetrahedra," *The American Mathematical Monthly*, 56, pp. 410–412, June, 1949.

[5] Trigg, C. W., "Problem 2184," SCHOOL SCIENCE AND MATHEMATICS, 50, pp. 407–8, May, 1950.

U. S. Commissioner of Education Samuel M. Brownell has reported that the highest peaks in school and college enrollments are yet to come. For 1954–55 elementary enrollments will be up 5.6 per cent with 1,473,000 additional pupils; high schools will have 219,000 more students, 3 per cent more than last year. It is a good time to alert ourselves to the nationwide trends and to appraise our own situation in light of these trends.

Writing good editorials is chiefly telling the people what they think, not what you think.—Brisbane.

PERCEPTIBLE CHANGES IN SCIENCE EDUCATION—1954

V. RONALD NELSON
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AND

STANLEY B. BROWN
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A recognition of the expanding role of science in the lives of all Americans is forcing our schools to re-examine our entire science education program. We are living in an environment so influenced by discoveries and inventions that the need for a fuller understanding and appreciation of the basic principles and potentialities of science is increasingly paramount and evident. This mobile and changing area demands a constant revision and adaptation of both content and method. Likewise, it becomes increasingly important that our youth attain a certain proficiency in the scientific approach to thinking, investigating, and studying.

Change in education is always a slow process. Sometimes it is difficult to weigh and measure trends within the field because of this slow adaptation to the needs of youth. Practices vary from community to community and only after a selective trial and error method are changes adopted. Even then, their acceptance is never universal. This fact makes it difficult to isolate permanent trends in education. The very nature of our democratic effort to provide an education for all American Youth has accented the practical, functional approach. Consequently certain trends in the teaching of science seem obvious enough when we carefully scan what is being done in an ever-increasing number of schools.

Trends in broad curriculum and methodology reorganization toward:

1. Traditional→Functional role of science teaching;
   - 1.1 The replacement of the traditional nature study by a broader, more functional, and coherent program of science which includes more physical science than formerly.
   - 1.2 An elementary school science which is not a watered-down mixture of high school biology, physics, and chemistry but an exploration of the problems existing in the natural environment of the child.
   - 1.3 Less college domination of the science curriculum with a more proportionate concern for the needs and interests of the non-college-preparatory group.

1.4 Higher enrollments in general science, biology, and physical science, but lower enrollments in physics and chemistry.
1.5 The kind of science course which is as applicable for the small high school as for the large high school, eliminating many of the more technical and more expensive courses found only in large high schools.
1.6 Science texts which are less college preparatory and encyclopedic but are more functional in the every day life of students.
1.7 Covering less material well—instead of covering all the material provided in the text.
1.8 Use of actual experiences, more doing, and less reading and hearing about science.
1.9 Use of a more practical laboratory manual which utilizes less filling-in of blanks and less experimentation on a cookbook basis.

2. Integration of science in the total school program;
2.1 A continuous, integrated, 12-year program of science planned for general education.
2.2 Offering integrated courses in science as a required course in the 9th grade in order to reach as many pupils as possible before they are eliminated. For a great majority of junior and four year high school students the science course or courses constitute a part of their terminal education.
2.3 Increased emphasis on science as an integral part of the school program—either as a separate course or in combination with social studies or some other area.
2.4 Science experiences and units built around the solving of real, meaningful, and socially significant problems—the solution of which involves materials from several subject matter fields.
2.5 More cooperative planning; administrators, teachers, and pupils planning and working together to execute an effective science program.

3. Enrichment opportunities in science teaching;
3.1 Enrichment of the science curriculum by means of additional elective courses appropriate for the resources of the community; size and facilities of the school; needs and interests of its pupils.
3.2 Development of course outlines by school systems and publishers to insure a sequence of subject matter from the kindergarten through senior high school and grade 14 where applicable.
3.3 The determination of curricular content after community

surveys have been made and an inventory compiled of those phases of community life pertaining to science.

3.4 The study of the application of scientific principles in the home, on the farm, in the industries of the community, and as related to the health, safety, sanitation, transportation and communication of the community.

3.5 Science texts authored by teams instead of individuals—teams often made up of a high school science teacher, a science subject matter specialist, and a science educator engaged in teacher training.

3.6 Greater utilization of community resources; for example, studying the birds of Middletown instead of the exotic birds of West Pakistan.

3.7 Seasonal organization of subject matter; for example, studying the flora which are native to the community and when they are present in the community.

3.8 The use of a wider range of materials and more extensive reading programs—several texts, periodicals, professional journals, and newspapers instead of a single text.

3.9 The organization of science clubs and science fairs as a means of enriching the regular courses.

4. Recognition of individual differences in the science program;

4.1 Fitting and adapting science offerings, methods, and content to the needs, interest, and abilities of youth instead of to the interest of scientists or what adults think our youth should be taught in the science program.

4.2 Science courses designed for all youth—the slow learner as well as the rapidly-maturing individual—rather than exclusively for the student who plans to continue his study of science.

4.3 Individualization of experiments on the basis of the student's unique interests.

5. The role of problem solving and scientific attitudes in science teaching;

5.1 An increased emphasis on the importance of problem recognition followed by individual and group usage of the basic steps of the scientific method of thought and experimentation for solution of those problems.

5.2 The use of situations in which the learner is required to organize, structure, and critically analyze the facts before formulating the desired answer.

5.3 The inculcation of desirable science attitudes such as objectivity, a respect for the cause and effect sequence, openmindedness, freedom from superstitions, an alternation of view when

additional or new evidence substantiates a new belief.

6. Administrative considerations in the teaching of science;
   - 6.1 Combination classroom and laboratory instead of different days for classwork and laboratory.
   - 6.2 The many fine public relation opportunities that carry over into the youth's everyday activities and family-community life as a result of his learnings in the science program.
7. Communication and keeping abreast with current happenings in science;
   - 7.1 More demonstration and lecture-demonstration work.
   - 7.2 A study of the most efficient techniques of demonstrating scientific laws and principles.
   - 7.3 Offering general physical science in the 11th or 12th grade as an elective course, providing both general and propaedeutic education.
   - 7.4 Offering survey courses in the biological and physical sciences on the junior college level; offered for general education along with pretechnical specialized courses.
   - 7.5 Texts utilizing a psychological organization of content instead of the logical arrangement of subject matter.
   - 7.6 The concept of a changing curriculum and changing curricular materials to keep step with changing communities, changing young people, and changing knowledge.
   - 7.7 More atomic energy materials in the various science courses to help meet the problems and challenges brought into being by the atomic-air age.
   - 7.8 Use of prepared diagrams and away from detailed, artistic drawings made by students.
   - 7.9 The identity of common misconceptions and superstitions frequently accepted by misguided youth and a clarification and recognition of the true fact of each.
8. Democratic values in the science program;
   - 8.1 Opportunities for the exercise of reason and intelligence in the many activities of students whether it be in the classroom, laboratory, field trip, or in the everyday functions of each student.
   - 8.2 A recognition of the sanctity and dignity of each student in the total school program. Mutual respect versus an erroneous bias or prejudiced feelings.
   - 8.3 A realization that through the cooperative efforts there is usually greater potential and unity than working on an individual bais.
   - 8.4 Giving attention to objectives which lead to modification of behavior as well as the objective of the acquisition of facts.

8.5 Development of experiments by means of group cooperation on the part of the students.

8.6 A realization that there is no one best way but that all methodology has a part to play in modern science education.

EXPERIMENTS INVITED FOR TAYLOR MEMORIAL LABORATORY PHYSICS

The American Association of Physics Teachers is undertaking the production of a book of Advanced Undergraduate Experiments in Physics, as a memorial to the late Lloyd William Taylor. The material is being supplied by the teachers of such laboratory courses; some one hundred physicists have contributed experiments and suggestions. In spite of this fine response, there may be many other interesting and illuminating experiments yet to be contributed, and these experiments also should be included in this book, to give them wider circulation and thereby to enrich the instruction in advanced physics courses. Every effort is being made to obtain them.

Although the primary responsibility for this book belongs to A.A.P.T. members, contributions are cordially invited from all physicists and from colleagues in other sciences, outside the United States as well as inside. All fields of physics are represented. Informally written notes, or laboratory instructions as used by students, are quite satisfactory, since the editors must put all material into publishable form. To be of use these experiments must reach the editors not later than March 1, 1955. They may be sent to T. B. Brown, The George Washington University, Washington, D. C., or to the appropriate editor. Sections and editors are *Mechanics:* R. H. Bacon, 405 Bedford Road, Pleasantville, N. Y. *Heat:* R. L. Weber, Pennsylvania State University, State College, Pa. *Acoustics:* L. R. Weber, Colorado State College, Fort Collins, Colo. *Electricity and Magnetism, Electronics:* M. C. Harrington, Drew University, Madison, N. J. *Optics:* H. A. Nye, Cornell University Aeronautical Laboratory, Buffalo, N. Y. *Atomic Physics and Spectra:* S. C. Brown, Massachusetts Institute of Technology, Cambridge, Mass. *Radioactivity and Nuclear Physics:* R. R. Palmer, Beloit College, Beloit, Wis.

UNSCRAMBLED MATHEMATICIANS

From page 679

(1) MALFATTI
(2) ERATOSTHENES
(3) RAPHSON
(4) ROLLE
(5) YOUNG

(6) CHASLES
(7) HARRIOT
(8) RAMANUJAN
(9) IAMBLICHUS
(10) SYLVESTER
(11) THALES
(12) MORLEY
(13) ANAXAGORAS
(14) STURM
(15) ARISTOTLE
(16) NEWTON
(17) DODGSON

(18) AGNESI

(19) HERON
(20) ARCHIMEDES
(21) PTOLEMY
(22) PLUCKER
(23) YANAGIHARA

(24) NICOMEDES
(25) EUCLID
(26) WIENER

(27) YANG HUI
(28) EISENSTEIN
(29) ARYABHATA
(30) RUSSELL

MATHEMATICAL FIGURES

FRANKLIN B. WELLS
Bloomfield College and Seminary, Bloomfield, N. J.

The figures presented here had for their inspiration the work of Boyd[1] whose design, based on inscribed equilateral triangles, has recently appeared as a cover background on a technical publication.[2] These figures start with an outer equilateral triangle, but unlike Boyd's figures, none of the inscribed triangles are equilateral. Two systems of figures are presented. In the first the equilateral triangle ABC is set up as in Fig. 1 and its center established at the point O. By rotating the line OC through an angle of some predetermined

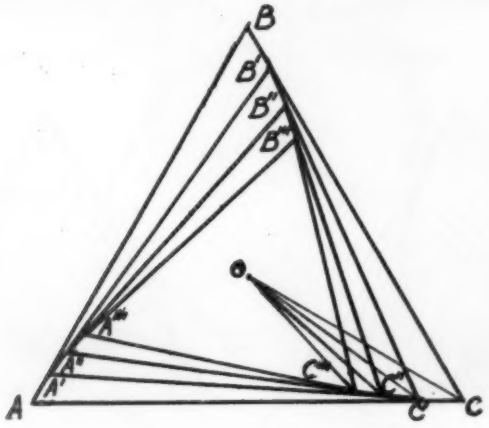

FIG. 1

magnitude such as 5°, its point of intersection with AC at C' is established as the lower right corner of the first inscribed triangle. The line AC' is next rotated about C' by a predetermined amount as for example 4°; its point of intersection with the line AB at A' becomes the lower left corner of the first inscribed triangle and the line $A'C'$ its base. The line $A'B$ is then rotated about A' by some amount such as 6°; its intersection with BC at B' is the apex and the line $A'B'$ one side of the first inscribed triangle which is completed by drawing the line $B'C'$. The line OC' is now rotated 5° to locate C'' on the line $A'C'$, the line $A'C''$ rotated 4° to locate A'' on the line $A'B'$, the line $A''C''$ drawn, the line $A''B'$ rotated 6° to locate the point B'' on the line $B'C'$ and the lines $A''B''$ and $B''C''$ drawn to complete the second inscribed triangle. This process is repeated to

[1] "Mathematical Ideas in Design," Rutherford Boyd, *Script Mathematica*, 14, 128–35 (1948).

[2] Epon Resins for Surface Coatings. Technical Publication SC: 52-31, Shell Chemical Corporation, 500 Fifth Ave., New York 36, N. Y.

inscribe any desired number of triangles. Such a system of inscribed triangles is named arbitrarily a 546OC system, the numerals designating respectively the three determinative angles and the letters designating the words "Original Center" meaning that the first angle

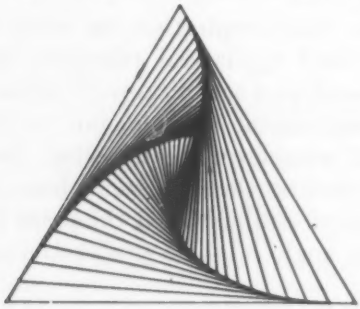

FIG. 2. 442OC

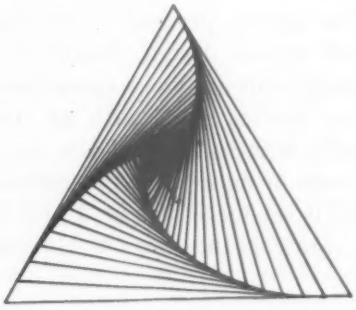

FIG. 3. 442NC

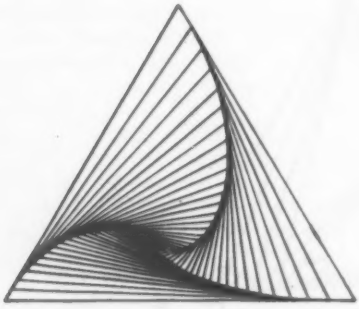

FIG. 4. 424OC

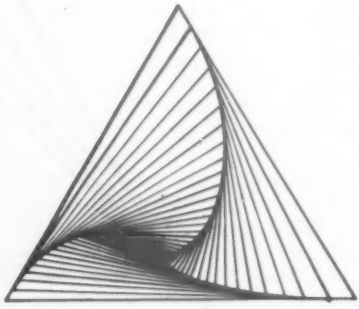

FIG. 5. 424NC

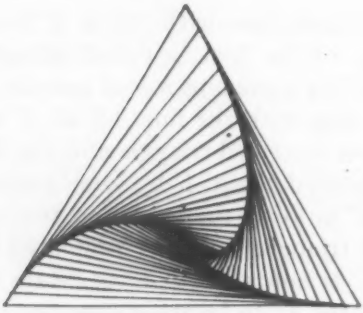

FIG. 6. 224OC

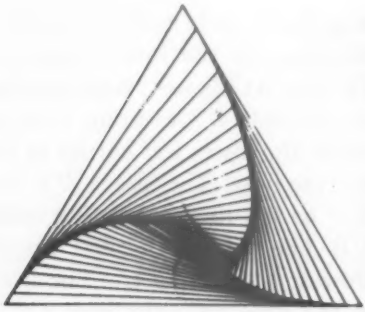

FIG. 7. 224NC

(of 5° in this case) is always rotated about the center O of the original equilateral triangle. Figures 2, 4 and 6 were developed on this system.

In the second system, the first inscribed triangle is developed as in the first system and its center O' established. The line $O'C'$ is then

rotated to establish the point C'', and the second inscribed triangle is then completed by the process of the first system. The center of this triangle $A''B''C''$ is established at O'', the line $O''C''$ rotated to find the point C''' and the third inscribed triangle developed as was the second. Again the process may be repeated to inscribe any desired number of triangles. Such a system has been called arbitrarily a 546*NC* system wherein the figures designate the three determinative angles and the letters designate the words "New Centers" which means that the first angle (of 5° in this case) is always established by rotation about the center of the previously formed triangle. Figures 3, 5 and 7 were developed on this system.

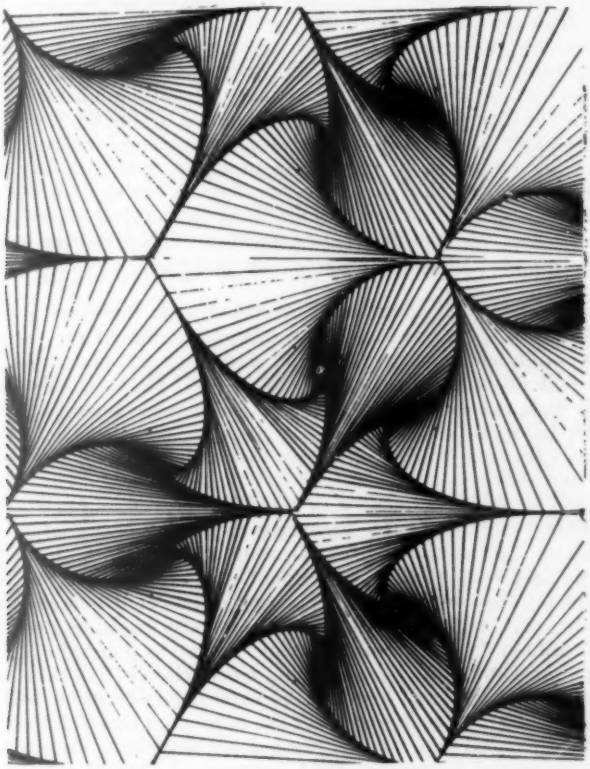

FIG. 8

The development of designs from these figures is not as simple as was the case for Boyd's triangular system which was entirely symmetrical. Both systems described above require that not only the original series but also its mirror image must be used to develope a proper design. Figure 8 illustrates such a design developed from the series of Figure 6 and its mirror image.

The illustrations serve to indicate the enormous variety of unique forms of considerable esthetic significance which are possible when Boyd's system is altered by making any one of the three determinative angles differ in size from the other two, or by making the three angles of different magnitudes. Obviously similar variations based on the square are also possible.

SCHOOL ENROLLMENT

The Nation's schools and colleges will enroll an estimated 38 million children and young people during 1954–55, according to S. M. Brownell, Commissioner of Education, U. S. Department of Health, Education, and Welfare. Commissioner Brownell's estimate was based on a survey, conducted annually by the Office of Education, on prospective school enrollments.

The upturn in number of pupils and students represents an advance for the tenth consecutive year, according to Mr. Brownell. The number of prospective enrollees represents 23 per cent of the country's total population.

In releasing the estimates of enrollment compiled by the U. S. Office of Education, Commissioner Brownell spoke highly of how communities throughout the United States have met school and college problems during the past 10 years.

"Citizens everywhere have made tremendous progress in providing for the education of our children," he said. "They have met crucial needs for classrooms and teachers during years of emergency in which high priorities were placed on critical materials and trained manpower for purposes of national security and world peace."

Commissioner Brownell pointed out, however, that there are many problems ahead. "The highest peaks in school and college enrollment are yet to come. By 1959–60 the enrollment in elementary and secondary schools and in colleges and universities will rise to approximately 46 million. High schools and then the colleges will feel the enrollment increase bulge now taxing our elementary schools," Mr. Brownell said.

"This year's increase in elementary and secondary school enrollment will be 1,692,000," according to the Commissioner of Education. "Elementary school enrollment will be up 5.6 per cent with 1,473,000 additional pupils. High schools will have 219,000 more students, 3 per cent more than last year.

"Colleges and universities will enroll about 89,000 more students this year than they did last year. College enrollment is now reflecting the Nation's low birth rates during the 1930's. However, larger numbers of young people, born in high birthrate years, will swell college and university enrollments by 1959–60 to more than 3 million," the Commissioner of Education pointed out.

"Although our communities are building more schools than ever before in any single period of our Nation's history, the rate of construction will have to be nearly tripled if we are to keep pace with the number of children to be educated," Commissioner Brownell said. "To accommodate the growing numbers of children, to erase the estimated September 1954 shortage of 370,000 classrooms, and to take care of continued obsolescence, approximately 720,000 public elementary and secondary school classrooms and related facilities will be needed during the next five years. About 50,000 classrooms will be provided this year."

It is not work that kills men; it is worry. Work is healthy; you can hardly put more upon a man than he can bear. Worry is rust upon the blade. It is not the revolution that destroys the machinery, but the friction. Fear secretes acids; but love and trust are sweet juices.

HENRY WARD BEECHER

A TEACHING DEVICE FOR REACTIONS RESULTING IN SHRINKAGE IN VOLUME

HAROLD J. ABRAHAMS
Public High Schools of Philadelphia, Pennsylvania

Among the difficulties which baffle beginning students in chemistry is the system:

$$2H_2+O_2 \rightarrow 2H_2O$$

2 volumes+1 volume→2 volumes (steam)

The balancing of the equation is straight-forward enough, but the use of the coefficients to interpret the volume relationships leads to the seeming fallacy that two volumes plus one volume yields two. This leaves the student with a feeling that he has wandered into a labyrinth from which there is no exit. The student is therefore confused by the demonstration in which ten volumes of hydrogen unite with five volumes of oxygen in the eudiometer, producing ten volumes of steam, not fifteen, as he would have expected.

The following device may be of use to teachers who like to rationalize such difficulties and thus demonstrate to their students that they are not asked, in science, to take things upon faith, but rather that a little penetrating thought frequently provides logical answers to seemingly illogical phenomena in Nature.

Six wooden blocks, each measuring $2\frac{1}{2}''$ by $2\frac{1}{2}''$ and $\frac{1}{2}''$ thick, were prepared and perforated in the center, so as to enable a two inch length of dowel, of $\frac{1}{4}''$ thickness, to fit rather tightly into the perforation. Four of these blocks were painted white and two painted black. Three dowel pins, each two inches long and $\frac{1}{4}''$ in diameter were also prepared. The white blocks were then assembled, two blocks on a dowel pin, producing two pairs. The black blocks similarly treated, produced one pair.

The explanation of the system

$$2H_2+O_2 \rightarrow 2H_2O$$

2 volumes+1 volume→2 volumes (steam)

may take the following form:

The teacher may ask a student to take a place in front of the class and arrange the blocks so that the white ones represent the hydrogen in the equation and the black ones represent the oxygen. When this is done there will be two pairs of white blocks and one of black. This of course represents the left side of the equation. Now, if the student has not yet drawn the inference that each of the blocks in the pair

represents one atom, or if some alert student has not yet volunteered the information, he may be told so by the teacher. He is now asked to change the arrangement of blocks so as to represent the right side of the equation. To do so he will, of course, have to pull the black pair apart and add one block (representing an atom of oxygen) to each white pair (representing two atoms of hydrogen). The dowel pins have been made sufficiently long to more than accommodate the third block. When the assembly is complete he will have two groups, each with two white and one black member (see Plate I).

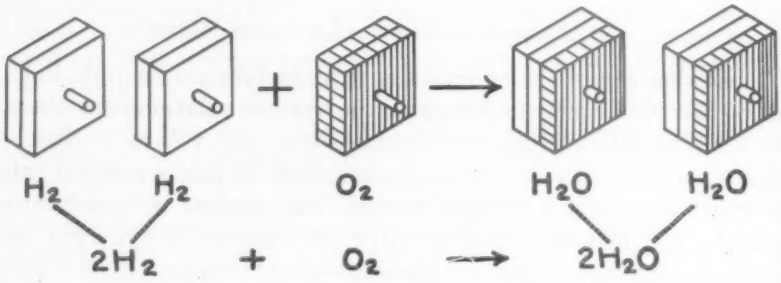

PLATE I

Questions by the teacher bring out the following points:

1) There were six individual blocks to begin with.

2) There were still six individual blocks at the end of the process.

3) Nothing has therefore been created or destroyed (this provides a review of the Law of the Conservation of Mass).

4) The apparent fallacy of two plus one yielding two is brought about by the fact that on the left side of the equation we are speaking of units, each of which consists of two parts (atoms), while on the right side the unit consists of three parts (two atoms of hydrogen and one atom of oxygen).

5) Our equation is therefore correct, as is the statement that two volumes of hydrogen plus one volume of oxygen yields 2 volumes of steam.

This device may be used in connection with the teaching of problems in Gay Lussac's Law, the Conservation Law and wherever else a teacher may find it applicable. It may prove useful in the presentation of the principle of Le Chatelier and Braun. If the number of blocks is changed to six white and two black, the device may be used for the system $N_2+3H_2\rightarrow 2NH_3$. Other uses will undoubtedly occur to the chemistry teacher.

We have been born to associate with our fellow-men, and to join in community with the human race.

CICERO

THE DIGITAL COMPUTER—A CHALLENGE TO MATHEMATICS TEACHERS

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Have you noticed any headlines like these in your newspaper lately?

"'Mechanical Brain' Does Basic Aircraft Research."

"Electronic Instrument to Forecast Weather."

"Department Store Merchandizing Control Given to 'Giant Brain'."

"Airport Traffic Control Managed by Digital Computer."

If so, you have been an observer of the debut into the world of practical affairs of some of the most remarkable machines ever constructed by man. These instruments, variously called Electronic or Mechanical Brains, Digital Computers, or Data Processing Machines are not new. Many of them have been in existence for a number of years and have been known by such colorful names as MANIAC, ENIAC, EDVAC, ORDVAC, OARAC, or SEAC. Part of these names stand for "automatic computer"; the Oak Ridge Automatic Computer and Logical Engine goes under the modest name of ORACLE!

Most of us have heard of the great value of these instruments in scientific work. We have read how complex mathematical problems in aerodynamics or ballistics—problems that would not even have been attempted before—are solved in hours or even minutes by digital computers. But what we must also realize is that the computer is by no means limited to research in higher mathematics. It is equally at home in any situation requiring the "processing" of information, regardless of whether it consists of the coefficients of a twelfth degree equation or the vital statistics of a group of insurance policy holders.

Let us consider an instance of the powers and the potentially great social effects of the "giant brain." Imagine the problems of merchandise control of a large chain of department stores. The management must keep track of the amounts sold of any article, together with details such as size, color, style, name of supplier, cost, sale price markdown if any, breakage or disappearance of articles, and a host of other things. Only by doing this can there be assured a smooth flow of materials without shortages, surpluses, over or underpricing, and so on. Today this job is handled by a veritable army of clerks whose sole function is the assembling, collating, and summarizing of information. The process is slow, expensive, and subject to many errors.

Now let us look into the future for a moment. The cash register rung up by the salesman will also punch automatically all relevant

information on a roll of tape at the time of sale. This roll will be flown to a central information processing center where an "electronic brain" will quickly print out a complete answer to any question about the multitude of transactions all over the country. Two important things will be accomplished. The first is the realization of the merchant's dream—a complete, up to date, running inventory of all his materials. Second will be the disappearance into the "giant brain" of thousands upon thousands of clerking jobs.

With the development of the industrial revolution the number of day laborers began to dwindle. Giant cranes, locomotives, machine tools, and bulldozers relieved mankind of the strain, monotony, and danger of physical work. But the clerk—the information processor—remained with us, and with the increasing complexity of modern life his numbers have grown. With the coming of age of the digital computer a second industrial revolution may well be close at hand. The first one relieved man of muscular drudgery and enabled him to change the face of the earth; the second may relieve him of mental drudgery and change society in an equally profound although perhaps less noticeable way.

How do these developments constitute a challenge to mathematics teachers? In several ways, First there is the challenge of our understanding the instrument itself. As guardians and disseminators of mathematics and of its ramifications in the culture of our own and other times we must perforce equip ourselves with a knowledge of important current trends. Only then can we answer our pupils' questions, or indeed arouse them to ask questions. The basic operational ideas underlying the digital computer are simple and important; they are well within the reach of any mathematics teacher. Some of these ideas will be given below; also I hope to follow this article with another that will set them forth more in detail.

Second, there is the challenge of guidance. The digital computer has literally overturned the market for mathematicians. Teaching has always been, and always should be an important calling for mathematicians. However, the days are gone when teaching is the sole economic refuge of a major in pure mathematics. Today the Ph.D. in mathematics who wishes to continue the cloistered life of the university scholar must resist the blandishments of a large number of computer firms that will offer him interesting work at many times an academic salary. The M.S., B.A. and even the promising undergraduate in mathematics will hear from these firms, particularly since digital computers such as the Remington Rand 1103 and the IBM 701 are moving almost into the mass production stage. Obviously grade, college, and vocational guidance advisers will also be involved in this important new economic development.

Third, there is the challenge to our teaching. Luckily the mathematics that will prepare pupils for understanding digital computers is the sort we have regarded as an objective of enlightened teaching. It includes a thorough knowledge of the concepts of variable and function, and of the methods of analytic thinking. It emphasizes basic understanding rather than technical details. Teachers of developmental arithmetic will be delighted to hear that it also includes a stress upon knowledge of the number system with special regard to the meaning of place values and scales of notation. In the long run the digital computer will cooperate with other modern ideas to revise and improve our mathematics syllabi; and it behooves the educators entrusted with these tasks to acquire expert knowledge of this new scientific ferment in the air.

Finally, there is the challenge of comprehending the social and cultural changes that may follow a second industrial revolution. There are signs that all this may not be far off. Much of the chemical industry is already controlled by automatic feedback devices which bear a relationship to computers. A good part of General Motors' billion dollar expansion program for 1954–55 will be devoted to automatic mechanisms. Traffic control, weather prediction, language translation, and many other human activities are being turned over to the efficient, rapid, and labor saving digital computer.

What will be the ultimate effect on our economic and cultural life? Will there be a new wave of technological unemployment? Will mankind, relieved of the last type of routine drudgery, demand a fuller and richer life, with a better use of leisure time? Or will he sink deeper into the morass of standardized and routinized entertainment? The digital computer will challenge the world of the future to answer these questions. In the meantime we mathematics teachers have a particular responsibility to understand its powers and its methods.

Let us close with a few general remarks about the nature of the digital computer. Basically, it is an instrument that is capable of carrying out a whole sequence of instructions or, as they are usually called, "orders." The feature of being able to follow a preassigned sequence of orders immediately sets the digital computer apart from even the most elaborate desk computer, which requires the intervention of a human operator at critical points in the solution of a problem. The digital computer must have the means to store these orders, in coded form, along with its storage of other data.

What may be the nature of the orders themselves? They must be very simple—far simpler than any you would worry about giving to the dullest pupil you ever taught. Essentially the computer has the power only to extract data from and record data into its storage sys-

tem, or "memory," to add signed numbers, and to amend the sequence in which it follows orders on the basis of its comparison of sizes of two numbers. These are called, respectively, "setting," "arithmetic," and "compare" orders. There are other orders of lesser importance, but these three are at the root of the instrument's operation.

Any problem that is to be fed to a computer must first be formulated logically and then broken down into a sequence of orders of the types mentioned above. A rough analogy exists in the instructions that accompany manufacturers' radio or television set kits, in which the complex task of wiring a circuit is broken into steps asking one to pick up such and such a part, wire this end of it to one point and that end of it to another. The analogy should not be pressed too far, especially since kit instructions do not contain "compare" orders.

Not only does the computer proceed automatically through its sequence of instructions, but it carries them out with extraordinary accuracy and incredible speed. Actually, the more time consuming element is not the "solving" by the machine—the answer is often printed out even before the operator has taken his finger off the starting button—but the original coding into a sequence of orders. This is quite in contrast to the hand solving of a numerical problem, where it often takes very little time to decide on what program to follow, but a very long time to carry it out. In fact, many of the algebraic algorithms we use are designed to reduce hand computation, despite their consequent possession of a more complex logical structure. One can see this by comparing, say, Newton's method of approximating real roots of an equation with a process of direct substitution.

Let us illustrate these ideas in a specific case. The equation:

$$\begin{aligned} P(x) \equiv \quad & 4.073x^{12} + 32.58x^{11} + 16.764x^{10} + 39.583x^{9} + 13.642x^{8} \\ & + 9.063x^{7} + 0.526x^{6} + 53.992x^{5} + 2.334x^{4} + 23.558x^{3} \\ & + 8.835x^{2} + 23.526x - 221 = 0 \end{aligned}$$

has, as can easily be verified, a single positive root that lies between 0 and 1. However, the process of approximating this root to 12 decimal places is decidedly less easy. Horner's—or possibly Newton's—method gives us a simple enough plan of attack, but the calculation quickly becomes quite formidable, although easier by far than that involved in a process of direct substitution. Any ingenious, computation saving device, no matter how logically complicated, will be accepted with relief by the hand computer.

With the digital computer, however, a directly opposite process is

followed. We must tax our ingenuity to devise the simplest method—logically speaking—of approximating the root, come what may in the way of extensive calculation. Then the sequence of orders will be less elaborate and the coding, which takes thousands of times as long as the actual machine solving, will be shortened.

The practical, machine method of solving the above problem is to locate the root by a process of successive bisections of the interval from 0 to 1. First a set of orders is given that causes the machine to evaluate $P(X)$ for $x=\frac{1}{2}$. Synthetic division reduces this task to a sequence of additions and multiplications, the latter being successive additions. When the answer is reached, in a matter of hundredths of a second, a "compare" order follows; namely, to compare the result with 0. The next order selected by the machine depends on the outcome of this order.

If $P(\frac{1}{2})$ is less than 0, the machine proceeds to an order to move to the *right* through half the remaining interval between $\frac{1}{2}$ and 1; that is, to substitute the value $\frac{3}{4}$. On the other hand, if $P(\frac{1}{2})$ is equal to or greater than 0, the compare order then programs the machine to move to the *left* through half the remaining interval, and therefore substitute $\frac{1}{4}$. After this the process is repeated.

As the reader can readily see, this method of alternate substitution and bisection can be crystallized in a general, recursive routine that will yield successively closer approximations to the root. It remains only to insert a final order to stop the machine when the interval length has reached the magnitude 10^{-12}. Then the answer will be printed, possibly on tape or a card, in about 30 seconds after the starting button is pressed. Of the 30 seconds about 25, on present machines, are used in storing information and printing the answer; only 5 seconds are used in actual "calculation"!

Most important of all, the sequence of orders, which can be coded for example on a deck of punched cards, can be used over and over to solve any number of similar equations. The sequence of orders, called a "routine," can be stored away as part of the "know-how" of the digital computer. As mathematicians use this machine they gradually acquire a vast storehouse of routines and subroutines that greatly increase its power and speed. The machine can be likened to an immense and infinitely flexible assembly line on which mass production of all types of information processing can be accomplished.

The above paragraphs only begin to describe the remarkable features of the digital computer, which is refashioning so much of our modern world. In these great new developments mathematics teachers will play a vitally important part.

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Laboratories and to Mr. Lawrence Finley of R. H. Macy and Co. for many of the ideas expressed in this article. The material on the twelfth degree equation was adapted from an article by Dr. Gorn that appeared in an Ordnance Publication.

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BIOCHEMISTRY BUILDING AT WISCONSIN

Groundbreaking for the new wing of the University of Wisconsin Biochemistry Building was held at 11 A.M. Thursday, Sept. 30, Conrad A. Elvehjem, chairman of the University's biochemistry department and dean of the Graduate School, announced Wednesday.

The new wing will be utilized exclusively for research. One floor will be devoted to work in plant chemistry; a second floor will be used for fermentation studies, and one will be used for research in biophysics. Two basement floors are included in the plans, and will be used for equipment and for a pilot plant to be connected directly with a large-scale fractionation apparatus for the production and isolation of compounds of biological importance.

The new wing will now consolidate the work in the field of biochemistry which is being conducted in many temporary and outlying buildings on the University campus, Elvehjem pointed out. It will, in addition, allow for some expansion of biochemical research.

Elvehjem said the new wing will also make it possible for the University "to continue training topnotch biochemists." More than 400 doctorate degrees in biochemistry have been granted by the Univesrity during the past 50 years, more than any other biochemistry department in the nation.

"The generous support of the Wisconsin Alumni Research Foundation has come at a time when we were faced with the decision of limiting our exapnsion or finding some way of solving the problems of space limitation," Dean Elvehjem said.

THE SOUTHEASTERN WORK CONFERENCE ON BIOLOGY TEACHING

The Southeastern Work Conference on Biology Teaching was sponsored by the National Association of Biology Teachers in cooperation with the American Institute of Biological Sciences. It was made possible by a $15,000 grant from the National Science Foundation and was co-directed by Dr. Richard L. Weaver, Associate Professor of Conservation, University of Michigan, and Dr. Samuel Meyer, Head of the Botany Department, Florida State University.

Attending and taking active part in the conference were nearly 100 men and women interested in various phases of biology teaching. The group included college professors of botany, zoology, biology and science education; high school teachers of biology; and supervisory and administration personnel including deans and state superintendents of education. Seventeen states, the District of Columbia and the Canal Zone were represented. Delegates from the American Association for the Advancement of Science, the National Research Council and the National Science Foundation took part.

RAINMAKING: A CONTEMPORARY SCIENCE PROBLEM

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One of the criticisms of the "case study" approach in a general education science program, such as given at Harvard University, is that the cases are antiquated ones drawn from the early history of science. Why not use contemporary cases? The answer usually given is that contemporary cases are too complex. This complexity may result from the amount of science background expected of the student for an understanding of the problem. The development of a modern scientific concept may be difficult to trace. In addition, the results of the application of a new principle may be difficult to state clearly. Yet the complete story of any case, historical or modern, is complex. Perhaps an appreciation of this very complexity is something worth passing on to present-day students.

The study of a modern case does have many advantages over one taken from the history of science. For one thing the basic documents of a modern case are easier to read that those of other centuries. No elaborate explanation of extinct concepts, such as phlogiston and *horror vacui*, is necessary in contemporary problems. Also modern problems are of more immediate interest to students than cases developed centuries ago. The possible use of motion pictures, tape recordings, and even lectures by some of the scientists concerned with contemporary problem is certainly more exciting than a few diagrams from old books.

In many ways the objectives for the education of students for citizenship and science understanding are better accomplished by a modern case than by a historical one.

The objectives for science education usually agreed on are as follows:[1]

"1. To acquaint the student with the scientific habit of thought and to encourage his using it in attacking problems of everyday living;
"2. To give an understanding and appreciation of science as one of man's great intellectual and cultural achievements;
"3. To impart sufficient knowledge of man's physical and biological environment to enable the student to function intelligently in relation to it;
"4. To disclose the impact of science and technology on contemporary life and to interpret some aspects of the social problems that arise from it."

With these objectives in mind let us consider the possibility of using rainmaking from 1940 to the present as a typical case. The following is a compressed and simplified story of weather modification.

[1] Cohen, I. Bernard and Watson, Fletcher G. *General Education in Science.* Cambridge: Harvard University Press, 1952, pp. 154–155.

Interspersed in the account are comments on related attitudes and methods of science.

The work on rainmaking began in 1940 with a study of the nature of filtration in gas masks. Dr. Irving Langmuir and Dr. Vincent J. Schaefer of the General Electric Research Laboratory in Schenectady did this work at the request of the Chemical Warfare Service, Their problem was to provide a filter that would remove toxic smokes. These men made toxic smokes, studied the particles, and learned to build a good filter.

COMMENT. This paragraph illustrates two principles relating to the growth of science. One is that a concept may evolve from experiments and technology not originally pointed toward that concept. The second is that the impact of society on science is as significant as the impact of science on society. The needs of the armed forces and the funds from government agencies tend to accelerate scientific investigation. The problems need not be formulated by scientists.

In August, 1941, Langmuir and Schaefer received a form letter asking if anyone could think of a way to make a white screening smoke that could be used over large area to cut down the hazard from enemy aircraft.

The scientists wondered if they could not make a screening smoke by methods they had adopted for making smokes for testing filters. They decided to try.

After further work and experimentation they found that they could make the screening smoke and control the size of the smoke particles on a large scale. Larger generators were built, tests were made, and the design was adopted by the Army and used during the war.

Other problems developed from the task of operating aircraft in the fogs and cold of the Aleutian Islands. The icing of aircraft and the loss of radio contact when planes flew through snowstorms were serious difficulties. The Secretary of War in 1943 asked particularly for research into precipitation static. When aircraft flew through snowstorms, the planes often became charged to potentials of 250,000 volts or more. Corona discharges would be produced all over the plane and radio sets would be useless. Pilots had difficulty reaching their bases and getting down in bad weather. How could this problem be solved?

COMMENT. Elements of chance may enter into the evolution of a concept. From all the requests that came to the attention of Langmuir and Schaeffer, a series reached them that resulted in a profitable outcome. These requests also came in a sequence that was useful to the eventual study of rainmaking.

To study precipitation static Langmuir and Schaefer placed some equipment on the top of Mt. Washington in New Hampshire during the winter of 1943. Schaefer discovered that anything exposed to the average 60 mph winds and four or five degree below zero temperature on Mt. Washington immediately became covered with ice. The air was filled with supercooled water droplets. The two scientists found this phenomenon very interesting.

Since the Army Air Force was just as interested in aircraft icing as precipitation static, Langmuir and Schaefer started to study aircraft icing, which was more closely related to their interest. Soon the scientists began to acquire an understanding of some features of cloud structure and the growth of cloud particles.

The top of Mt. Washington is covered by clouds most of the time, and the scientists were able to arrive at a theory for some of the factors that caused particles to grow in clouds. However, the scientists believed that it would be better to study particle growth in airplane flights. But although they tried, they could not obtain an airplane from the armed forces for this purpose.

COMMENT. New concepts evolve from previous experiments and observations. The relationship of the scientists' work to their final basic theories now is apparent. Particle size was one factor common to studies of toxic smokes, screening smokes, and aircraft icing. Smoke generators were basic for the technology.

In 1946 Schaefer turned to the laboratory to attempt to duplicate cloud conditions. He eventually decided to use a home freezing unit. He lined it with black velvet so that he could see what happened when he shone a beam of light into the box. After many experiments he found that even a tiny grain of dry ice would transform the supercooled "cloud" in the home freezer to ice crystals. He also determined that the critical temperature at which the supercooled "cloud" turned to ice crystals was about −39°F.

COMMENT. The duplication of natural conditions in a model in the laboratory is often a vital step in the scientific process. The use of the home freezer in this instance was a brilliant improvisation for cloud conditions. The lack of readily available equipment and instruments must frequently be a limiting factor in the development of a concept.

In the meantime Dr. Bernard Vonnegut at Massachusetts Institute of Technology had been working on smokes for the government's Chemical Warfare Service. Later he became interested in the problem of aircraft icing and also did some work on supercooling. In 1945 he became employed at the General Electric Research Laboratories and began to work with Langmuir and Schaefer.

It occurred to Vonnegut that some crystal similar to ice crystal might prove to be a good nucleus for the formation of ice crystals. He examined the crystal data in a handbook listing 1900 known crystals. He found three substances that he thought might have possibilities: lead iodide, antimony, and silver iodide.

COMMENT. A problem may be simplified by establishing limits for factors. The scientist reached first for a handbook of crystals. Out of 1900 possibilities he chose three to test.

He dropped samples of each of these three materials in powder form into Schaefer's cold box. With the exception of the lead iodide the results were almost negligible. Vonnegut than decided to try a metal smoke instead of a powder. He introduced some silver smoke into the box by drawing an electric spark from a piece of silver. The result was a spectacular swarm of crystals.

However, the effect with silver did not persist. He decided to try silver iodide as a smoke rather than as a powder. First he vaporized the silver iodide, and then he introduced into the cold box the smoke resulting from the rapid condensation of this vapor. Large numbers of ice crystals formed in a cloud. The experiment was a complete success.

Why didn't the silver iodide work as a powder? Vonnegut found that his original samples were impure. Powdered silver iodide did work when it was reasonably pure. He then found that the powdered lead iodide worked because it was contaminated by silver.

His further study indicated that silver iodide is not quite as good a nucleus as ice itself. The ice crystals produced by the use of dry ice can grow at any temperature up to 32°F., the freezing point of water. Silver-iodide particles on the other hand produce crystals only when the temperature of the cloud is 26°F. or less. Silver iodide has the advantage, however, in that it, unlike ice, does not melt or evaporate in the atmosphere. Therefore, silver iodide need not be dropped directly into clouds. The laboratory experiments showed that one gram of silver iodide in smoke form should provide enough nuclei to seed from 100 to 1000 cubic miles of supercooled clouds. These facts gave the scientist the idea that silver-iodide smoke could be sprayed into the air from the ground.

COMMENT. Trivialities sometimes apparently invalidate conclusions. The samples used proved to be impure. However, the scientist did not discard his hypothesis; he revised his technique.

Meanwhile Langmuir and Schaefer decided to try an experiment by dropping dry ice from an airplane into a natural cloud. On November 13, 1946, Schaefer and a pilot flew in a hired airplane searching for a suitable cloud. Langmuir watched from the ground at Schenec-

tady, N.Y. At 14,000 feet over Mt. Greylock in western Massachusetts they found a supercooled cloud. It was a few thousand feet thick and about four miles long. As they flew over it, Schaefer dropped about three pounds of dry ice into the cloud and then looked back. The entire cloud began to change in appearance and long streamers of falling snow appeared. These streamers were visible to Langmuir 40 miles away.

Soon afterwards the officials of General Electric Company took serious interest in the program of weather modification. Everyone was agreed that the results of the trials were possibly of great significance to the country. Because of this and because of the fact that government was needed to provide weather data and airplanes, a government contract was sought. G.E. officials also realized that the company might be liable to extensive damage suits from cloud-seeding activities.

Finally a contract was arranged with the U. S. Army Signal Corps and the Office of Naval Research with cooperation from the U. S. Air Force. The program of cloud seeding and tests extended from February 28, 1947 until September 30, 1952. This program was named Project Cirrus.

COMMENT. The predictions of science are a significant part of its usefulness. However, scientists recognize that laboratory work is usually only a simplified model of natural conditions. The conditions inside a home freezer may not be the same as those of a cloud.

Without government support and protection, this investigation might have been stopped at this point.

The use of government funds, data, and equipment enabled the research scientists to broaden their field of operations. Tests flights with specially designed instruments were flown over New York, Pennsylvania, Vermont, New Hampshire, Florida, New Mexico, Puerto Rico, Honduras, and Hawaii. Silver-iodide generators placed on the ground were used in New Mexico.

Some evaluation of the results of the various seeding experiments was made by the use of motion pictures and stills. Special techniques, such as color photography, time-lapse pictures, and three-dimensional pictures were also used. Many new instruments were designed or old ones were adapted to new purposes.

COMMENT. The development of instruments to collect and record data is a significant part of scientific progress. The use of instruments improves accuracy of observation.

In the determination of the validity of the results of increasing rainfall by artificial means two general methods are used. In one the

amount of rainfall following seeding operations is calculated as a percentage of normal rainfall. In the other method the amount of rainfall in a target area following seeding operations is compared with rainfall in a nearby control area not seeded. The historical data of rainfall in the two areas is also considered.

The problem of evaluation of results in cloud seeding is a critical one. How can one be certain that the precipitation following seeding would not have occurred naturally? Statistical significance depends on control of variables, and the evaluations of many of these must be subjective.

Laboratory work continued during the project. Some of the studies were on the structure of snowflakes and raindrops, condensation nuclei, cloud types, and the formation of ice crystals.

One important study made during the time of Project Cirrus was the plan to introduce, if possible, a seven-day periodicity into the weather cycles of the nation. This experiment has been called one of the strangest and most controversial in the history of science. Langmuir seeded the atmosphere by releasing silver iodide from a generator at Socorro, New Mexico, on Mondays for eight weeks and then shifted to Fridays for eight weeks, and then back to Mondays, and so on. Langmuir's intention was to show that if there was a phase shift in the weather in the East which followed the phase shifts of the generators, there would be strong evidence of the power of silver iodide to modify the weather.

According to Langmuir's interpretation of the data this phase shift took place. According to Glenn W. Brier, chief statistician of the Weather Bureau, evidence of a phase shift occurred only in a few southeastern states and not anywhere else. Brier contended that the widespread absence of a phase shift made its appearance in one region statistically insignificant. Langmuir argued that many other generators were in operation north of his during the trials and that these affected the results in the Northeast.

COMMENT. The controversy between Dr. Langmuir and members of the Weather Bureau underlines the significance of the interpretation of statistics in a science problem.

While the fundamental concepts and the value of rainmaking are being argued, commercial rain stimulators are being hired throughout the world. Three large companies and many smaller ones do an estimated million dollars worth of business a year. Many water-users are convinced that seeding in their areas has resulted in increases of rainfall 15 to 25% above normal. The cost of seeding (sometimes as little as 5¢ per square mile) makes the operation economically

attractive. In general, the reactions of the public regarding the use of state or city funds for such a purpose are favorable.

However, while some people may want rain at a particular time, others may want fair weather. Conflict of interest may bring up the problem of liability. Are commercial companies liable for damages resulting from cloud seeding activities? For example, W. E. Howell, a commercial rain stimulator, and New York City are being sued for $2.5 millions as a result of claims for damages a few years ago. The case has not yet been settled in New York courts.

In seven states, Oregon, Colorado, Wyoming, California, Massachusetts, Arizona, and New Mexico, legislation has been passed to provide controls on weather modification activities. Congress in 1953 passed a bill establishing an Advisory Committee on Weather Control. The Committee is investigating weather modification and its relationship to national welfare. It is expected to report not later than June 30, 1956.

COMMENT. The impact of science on society is clearly shown in this account.

Conclusions

The use of a modern case history, such as rainmaking, familiarizes students with scientific habits of thought. The use of such a case may help to give students an understanding and appreciation of science. A knowledge of some of man's physical environment is brought to the students. And finally, the students are able to grasp the impact of science and technology on everyday life and to have an opportunity to study some related social problems.

In a study of rainmaking some general aspects of scientific inquiry are developed. The points of controversy at scientific level bring out the necessity for additional research. An overview of operations thus far indicates a lack of coordination between private investigators, commercial rain stimulators, and government offices. Possibly a standardized method of designing experiments is needed. Finally, the method of evaluating results needs to be agreed upon.

For students the analysis of the problem and the making of recommendations for future actions would stimulate them to discover for themselves something about scientific methods, scientific attitudes, and the impact of science on society.

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A STUDY OF BIRDS IN AFRICA

Africa offers a wealth of opportunity for scientific research, and it is a land that presents enormous contrasts in its vegetation, peoples, birds, and animals, says John T. Emlen, University of Wisconsin professor of zoology, who has returned from a year's research in Southern Africa on Guggenheim and Fulbright research grants.

Emlen left Wisconsin a year ago, taking along his wife and three sons. Since that time his field work in Africa has taken him to many parts of Southern and Northern Rhodesia, Bechuanaland, to the borders of Southwest Africa and Portuguese East Africa, and to the Union of South Africa.

Headquarters for Emlen was Bulawayo, site of the national museum of Southern Rhodesia, which sponsored his studies, and from there he traveled through the adjacent African countries in a 1941 Chevrolet, accompanied on many of the short trips by his family and by native assistants or museum personnel on longer, more arduous expeditions.

Emlen's purpose was comparison of the behavior and habitat preferences of certain African bird species which are related to American species and, also, to investigate and attempt to learn how some species which are not related came to have nearly identical habit patterns and plumage.

Information obtained in such studies is of great help to scientists interested in the manner in which birds and animals—including man—develop behavioral characteristics which are just as distinct as characteristics of appearance and which are also transferred from one generation to the next.

OFFICE OF EDUCATION ESTIMATES OF ENROLLMENTS FOR 1954–55 AS COMPARED WITH THOSE FOR 1953–54

Secondary Schools	*1954–55*	*1953–54*
Public	6,582,300	6,388,000
Private & Parochial	774,800	751,200
Residential schools for exceptional children	11,100	11,100
Model & practice schools, teacher training	40,500	40,000
Federal schools for Indians	12,300	11,800
Federal schools, P. L. 874*	1,000	900
Total secondary	7,422,000	7,203,000
Other Schools		
Private commercial schools	144,000	131,000
Nurse training schools (not affiliated with colleges)	69,500	71,900
Total other schools	213,500	202,900

Source: Office of Education Statistical Circular No. 408, August 1954.
* Includes only "schools operated on post by a Federal agency."

A MATHEMATICS CLUB FOR FUTURE MATHEMATICIANS

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There are in most high schools, subject matter clubs organized for various purposes and achieving different aims.

Many mathematics clubs devote considerable time to the recreational side of mathematics, such as puzzles and trick manipulations. Others are concerned with the enrichment of the program by the solution of rather complex problems and original exercises requiring a degree of mathematical maturity often found in the capable secondary student. There are clubs organized for purposes of enlightenment and guidance of the student in planning his career and future mathematical training. Still others serve as a meeting ground for social activities of those with similar interests and abilities.

The content and purpose of these club programs are laudable and fulfill a definite need in the school community.

This article is a report of the activities of a mathematics club for future mathematicians and research scientists. This type of club may not be organized in every high school, but when a teacher finds several youngsters with superior mathematical ability who are apparently not sufficiently challenged in the classroom, that teacher may offer these students a challenge in a mathematics club designed for high school pupils who may be future mathematicians, scientists, physicists, research engineers, philosophers and other leaders of tomorrow's educated world.

In my math classes at a New Jersey high school, I had several young men who needed this challenge, and a Mathematics Club for Future Mathematicians, so to speak, thus fulfilled a definite need in this instance. In such a club, talented students who take their subject matter seriously may enlarge their enthusiasm for mathematics while developing their aptitude for the subject. Here they prepare themselves in part for the transition from high school classrooms dealing with mathematical "problems" to college lecture rooms concerned primarily with mathematical research. By enabling these students to make this transition—often a difficult one—the Math Club helps to assure them of future success in their chosen fields.

Being adviser of such a Math Club can be a source of delight to the mathematics teacher who loves his work and seeks to help his students.

The only stipulation placed on membership in a Math Club of this type was that students must do independent study and be prepared

to read their original papers before the group. Any student in the high school who wished to do this could join the club.

There were fourteen students in the small New Jersey high school who brought their enthusiasm to this club. To these students topics for investigation were assigned. These topics were suggested by their classroom questions, and by inquiry which revealed in what areas of specialization their interests lay. In this group were young men who wanted to become scientists, physicists, engineers, and pure mathematicians. There were also students who had no future profession selected, but who had an inherent interest in mathematics.

Members prepared papers on topics including the following: Linear Algebras and Matrix Theory, DeMoivre's Theorem, Theory of Sets, Concept of Limits, Probability, Mathematical Analysis of Infinity, Infinite Series, Boolean Algebra, Real Number, Transfinite Number, Factor and Remainder Theorems, Indefinables, Sketching of Algebraic Curves by Means of Sign Lines, and other selected topics in Calculus.

Using books which were provided, they learned how to conduct independent study in a given topic, how to select portions of articles for their contents, how to write original papers. In reading these papers before other members at the weekly meetings, they obtained a measure of poise and self-confidence. In the colloquium discussions which followed the reading of each student's paper, members learned how to criticize objectively, while the young man who had prepared the paper learned how to "take" that criticism and profit by it. Students who prepared papers were able to answer questions on the topics which were not immediately covered in the papers, thus revealing a growing understanding of various phases of the subject itself.

These students soon learned that mathematics is not merely manipulation. It is also a philosophy and is to be found in all branches of science. Mathematics has played a great part in the culture of all civilizations. It has brought about the great inventions of our times.

With an increased knowledge of the subject which concerned the club, members' enthusiasm waxed even keener and the popularity of the club grew. Character-building was aided as members, in learning how to do independent study learned also how to trade ideas as they had traded marbles when they were younger, and how to improve their own intellectual habits. Instead of meeting once a week, members voted for twice-a-week meetings, to give them opportunities to present more papers and hold longer discussions on topics which interested all club members.

In this particular high school community there were many men and women who were research physicists and mathematicians with research laboratories. Some of them were visitors to the Math Club.

Many had heard of the work that the students were doing and professed disbelief. They were astounded by the level of attainment of these students. A woman who was a mathematician with a research chemical laboratory in northern New Jersey told me, "This is unbelievable. I never knew that students of high school age were capable of research. They will not realize how fortunate they were in belonging to this club until they reach college and find themselves on familiar ground when research topics are assigned."

Parents were interested in the club and sometimes visited our meetings. Many parents expressed themselves as anxious to assist their children in making a successful transition from high school to college and in sustaining and developing their interest in mathematics. One boy in the club said that his father, an engineer with a firm in New York City, discussed his son's assigned topic with him, offered him books for research, advised him on preparing his paper, and approved wholeheartedly of the Math Club's serious attitude toward his son's future.

Many members of this particular Math Club were offered scholarships by colleges, including the University of Chicago, Johns Hopkins University and Columbia University.

As for mathematics students who were not members of the club, there was no resentment because, by exerting themselves, they could very easily become club members, and many of them did just that. Others were sufficiently challenged in the classroom and did not wish to pursue mathematical study outside their daily classroom work.

There were numerous other clubs in the school, answering various needs in subject matter and recreation, which also took the time of mathematics students and Math Club members. Some of these clubs provided students with parties, square dances and amusements. Others gave them additional knowledge in various fields. Advisers of these clubs heard of the Math Club's success and adopted some of its attitudes as applied to other subjects.

Other mathematics teachers in the school conducted private study of their own, and many teachers new in the profession made attempts to sharpen their own knowledge in order to cope with Math Club members who were in their classes. A famous educator has said, "You cannot teach up to the edge of what you know," and we are aware that a teacher must know more than he teaches. In all high schools are teachers who seek constantly to improve their own knowledge and to answer classroom questions and give aid to all sincere students—those below average, those who are average, and those who are superior in ability.

Because experimentation is necessarily limited in the classroom, the different types of Math Clubs fulfill definite needs. In a school

with a number of students who are mathematically talented, anxious for future study in this subject, and ambitious for successful mathematical or scientific careers, a Mathematics Club for Future Mathematicians may prove invaluable to these students, the teachers and, in time, to the school itself.

THE INTERNATIONAL FRIENDSHIP LEAGUE

Many teachers report that students who have made pen friends in other countries have exchanged information, pictures and general impressions and explanations in a way which has given them a new interest in their courses.

Often they bring results of their correspondence to class with all the pride of explorers who have made personal contacts far away, and shared their enthusiasm with the whole group.

All this makes it easier for teachers to arouse and hold interest. The International Friendship League of Boston offers the opportunity of having pen friends in more than 100 free dominions and territories of students from eighth through twenty-eighth years of age.

Members of the League are not only finding real fun and adventure in their pen pal relationships, and an incentive to throw themselves more happily into their school work, but are actually serving as goodwill ambassadors for their country.

The value of their influence has now been given official government recognition. This year one of the first Certificates of Merit to be awarded by the United States Information Agency was received by the International Friendship League, ". . . in recognition of outstanding assistance to the International Information Program in behalf of peace and freedom by cooperating in projects designed to promote better understanding of the United States in other countries and mutual understanding between the people of the United States and the people of other countries."

"I feel," said Theodore C. Streibert, director of the USIA, "that the International Friendship League, its director and members, have made a noteworthy contribution in furthering understanding and friendship abroad for the United States and its people."

Any teachers interested in laying this opportunity before their classes are invited by the League to send a self-addressed envelope requesting a free supply of official application blanks to:

International Friendship League
40 Mount Vernon Street
Boston 8, Massachusetts

Many names of teachers abroad anxious to be put in touch with American teachers are also in the League's files.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

The first students have registered this fall for a new five-year program at the Massachusetts Institute of Technology which prepares for careers in management for the shipping and shipbuilding industry.

Five years of study in the M.I.T. Department of Naval Architecture and Marine Engineering will lead, under the new course, to two degrees awarded simultaneously: the Bachelor of Science in Naval Architecture and Marine Engineering and a new Master's degree, the Master of Science in Shipping and Shipbuilding Management.

The new course in shipping and shipbuilding management and the new master's degree to which it leads were approved by the M.I.T. faculty last spring; the new degree is expected to be awarded for the first time in the commencement exercises of June, 1955, according to Professor Laurens Troost, head of the department.

MAGNETISM

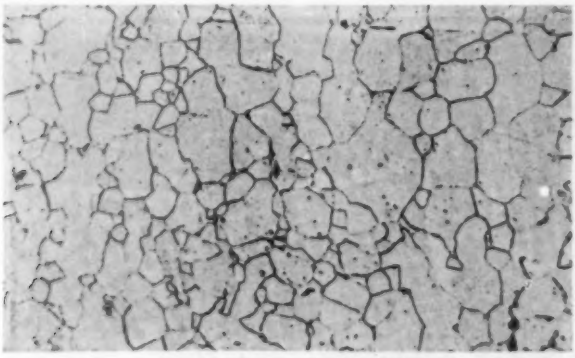
S. R. WILLIAMS
Amherst College, Amherst, Mass.

CHAPTER V

WHAT MAKES FERROMAGNETIC BODIES CLICK THE WAY THEY DO?

When a ferromagnetic body is magnetized, the things which happen constitute many of the phenomena of magnetism. In order for these things to occur there are certain essentials a substance must possess before it can produce them. It is with these essentials that this chapter will be concerned.

Crystals. Many substances with which we deal in physics are crystalline in their structure, either monocrystalline or polycrystalline. Fig. 4 showed a monocrystal of magnetite, while Fig. 50 shows a cross section of a polycrystalline structure of pure iron. The dark lines represent crystal boundaries. It is obvious that they do not possess the regular geometrical outlines found in typical crystals which have been permitted free development,—on the contrary, the boundaries of the crystals in a metal are merely the surfaces upon



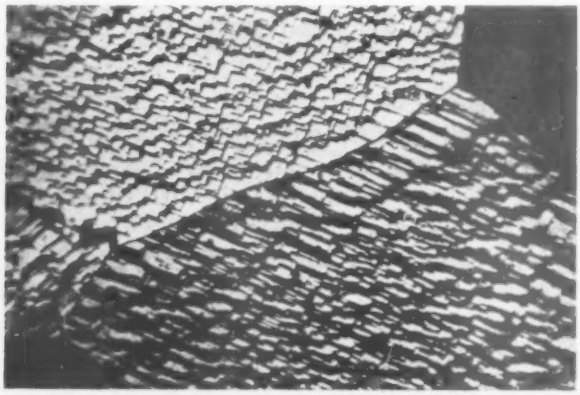
Courtesy of A Dictionary of Applied Physics, *Macmillan and Co., Ltd.*

FIG. 50. The black lines indicate the boundaries between the crystals in a specimen of pure iron.

which adjacent crystals have met in the process of growth during their formation. Fig. 51 shows a surface of steel which has been etched to indicate these grains or crystallites in 3 dimensions. Fig. 52 shows how the small crystals grow until they meet crystals growing out from another direction. Where they meet are the crystal boundaries. The interior of each set of grains is truly crystalline in the sense that within each grain there is a uniform geometrical orientation, but

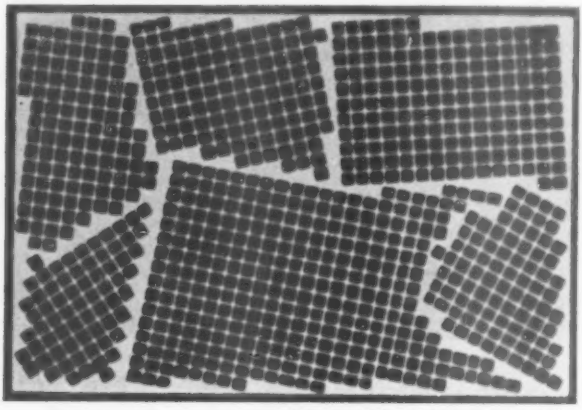
this orientation in one grain is different from that in another. This idea may be gathered from consideration of Figs. 51 and 52 once more. It may be mentioned in passing that all ferromagnetic metals have these crystal boundaries shown in Fig. 50.

In studies of ferromagnetic bodies we shall be working either with



Courtesy of A Dictionary of Applied Physics, *Macmillan and Co., Ltd.*

FIG. 51. The surface of a piece of iron etched to bring out the crystal structures and boundaries between them.



Courtesy of Bell Telephone Laboratories

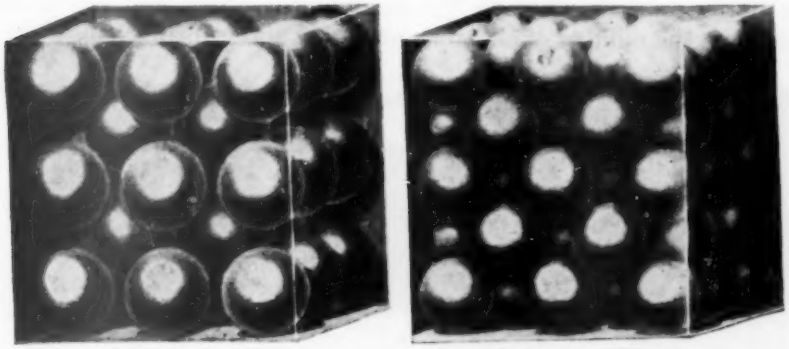
FIG. 52. A drawing to help visualize what one sees in Figs. 50 and 51.

monocrystalline or polycrystalline structures, and the crystalline structure of the substance being studied will influence the results tremendously.

Emphasis is being laid on crystalline structure, because we wish to get a clear distinction between crystals and ferromagnetic domains, which we shall presently consider.

Each crystal of iron is composed of a fundamental unit consisting of nine atoms. This is the unit for alpha-iron, and is known as the body-centered cubic crystal containing nine atoms, one at each corner of the cube and one at the center. Above 770°C. alpha-iron changes to gamma-iron, and becomes non-magnetic. In this form the fundamental crystal unit is a face centered cube, which means that with the eight atoms at the corners and the six atoms in the center of the six faces there are 14 atoms in the face centered unitary cube. In Fig. 58 it will be seen that nickel, which is ferromagnetic also, has 14 atoms in its fundamental crystal cube, and is therefore face-centered cubic.

In Fig. 53 is shown the arrangement of the atoms of iron in the alpha and gamma forms of iron. It will be observed that for any given crystal all unit crystals are oriented with their axes in the same direction.



Courtesy of Bell Telephone Laboratories

FIG. 53. Arrangement of atoms in a crystal of alpha-iron, (a) body-centered cubic lattice. Atoms as laid up in gamma-iron, (b) face centered cubic lattice. Alpha-iron is magnetic.

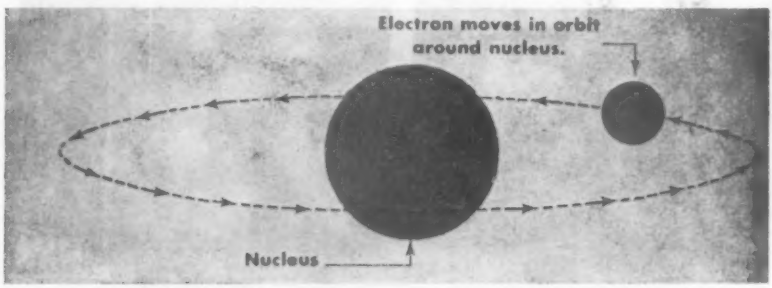
In a polycrystalline aggregation the actual crystals present will be oriented into a hodge-podge fashion as shown in Fig. 52, but in each crystal the unit iron crystals of nine atoms are laid up in an orderly manner. It is with alpha-iron that we shall be most concerned.

Iron Atoms. The atoms of iron, nickel and cobalt are peculiar to the ferromagnetic family. In Chapter 4 we discussed the properties of the elementary magnet, the spinning electron. These elementary magnets are a part of the iron atom, and therefore of concern to the magnetician.

According to the Bohr theory, atoms, while differing among themselves, have a basic likeness in that each one has a central nucleus about which revolve spinning negative electrons like the planets about our sun. For instance, in Fig. 54 is shown the simplest atom,

that of hydrogen, which consists of a nucleus composed of a positively charged mass called the proton, around which revolves a single negative electron. The mass of the proton is about 1838 times greater than that of the spinning negative electron which revolves about the nucleus or proton. From Rutherford's work it would appear that the diameter of the proton is much less than that of the negative electron, if definite radii can be ascribed to these two entities.

The second element, helium, in the atomic series becomes more complicated, the complication increasing with each succeeding atom in the scale. The atom of helium has in its nucleus two protons and two neutrons around which revolve two spinning negative electrons. The neutrons are masses about equal to those of the protons, but neutral so far as electric charges are concerned. Hydrogen has for its designation atomic number 1, represented by $_1H^1$, while helium has atomic number 2 for its designation, represented by $_2He^4$ where the upper number refers to the mass of the atom, and the lower number is the number of electrons revolving about the nucleus.



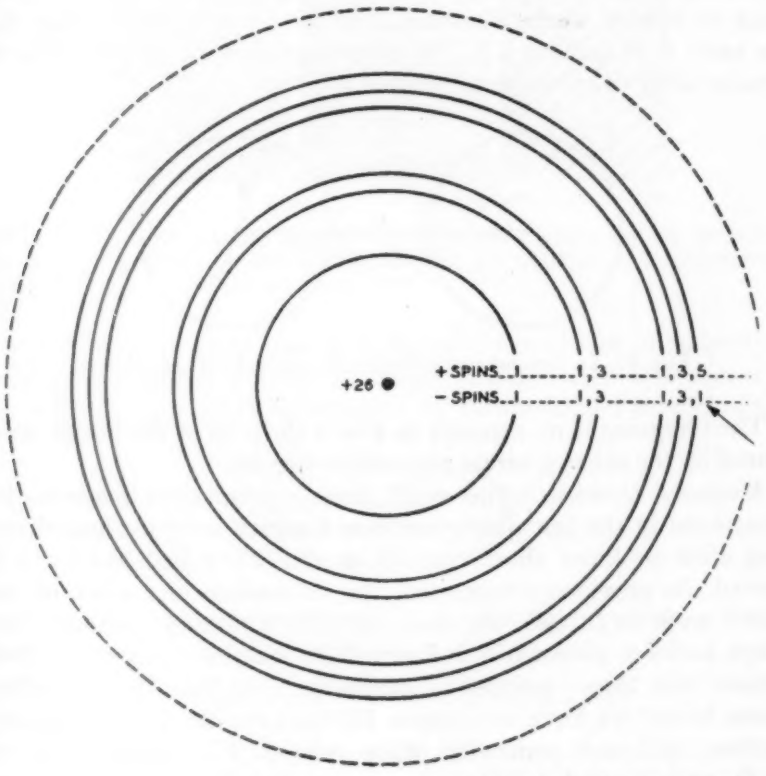
Courtesy of Bell Telephone Laboratories

FIG. 54. Bohr's picture of the Hydrogen Atom. As the negative electron revolves about the positive nucleus (proton) it rotates on its own axis like a top. The mass of the proton is about 1838 times greater than that of the electron. The Figure is drawn to show the greater mass, although the volumes are in a somewhat inverse ratio.

By the time we reach iron in the series with atomic number 26 and mass 56, $_{26}Fe^{56}$, the complication is still greater. It possesses 26 protons and 30 neutrons in its nucleus for the ordinary iron atom with 26 negative electrons revolving around the nucleus.

In the Bohr idea of negative electrons revolving about the nucleus, it has been found expedient to have them circulating in special concentric shells. Fig. 55 shows a plan for the 26 electrons which revolve about the iron nucleus. The striking fact about this arrangement is that there are two electrons in the fourth or outer shell before the total number to fill the third shell has been completed. The two outer electrons, when the atoms are bound together in a solid, wander about

from atom to atom and are the free electrons which participate in the electrical conductivity of iron. It will also be noted that among the remaining 24 electrons, 14 of them have so-called positive spin and 10 negative spin. It is the four unbalanced positive spins in the third shell which make the iron atom distinctively ferromagnetic. An analogous situation exists in nickel and cobalt. In a sense these unbalanced spinning electrons in each ferromagnetic atom become the real elementary magnet for that particular substance, although the single spinning electron is still the most fundamental.



Courtesy of Bell Telephone Laboratories

FIG. 55. Showing the various shells in which the electrons revolve about the nucleus of the iron atom.

Since there are other atoms having this imbalance of positive and negative spins of the electrons which are not ferromagnetic, another factor must be coupled to this imbalance to make an atom distinctively ferromagnetic. The atoms cannot be too close together. According to the atomic experts and wave mechanicians, there is a need for some internal force competent to hold neighboring atoms

parallel to each other, or, as Bozorth[1] states it, "the small atomic permanent magnets of each group must point in the same direction so as to provide a magnetic moment great enough to permit a realignment when subjected to external fields. This force turns out to be electrostatic in its nature, and maintains small groups of atomic magnets parallel against the forces of thermal agitation. Such a force is called "exchange interaction." At 77°C. the thermal agitation does overcome this parallelism, and the iron loses its ferromagnetism.

To get just the right condition for this parallelism which produces ferromagnetism, the distance L between the centers of atoms, Fig. 56, must be related to the diameter D of the atom in such a way that the ratio L/D exceeds 1.5. The ferromagnetism of an alloy like the Heusler alloy can thus be accounted for.

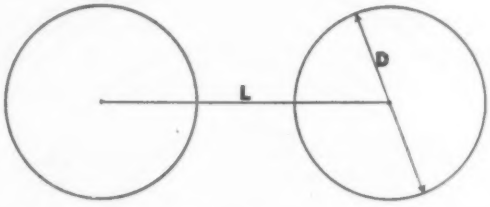


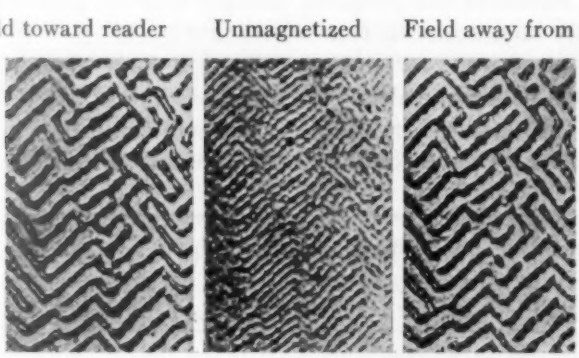
FIG. 56. In ferromagnetic bodies the ratio L/D exceeds 1.5.

The foregoing is an attempt to give a close-up of the atoms represented by the spheres within the cube in Fig. 53.

Magnetic Domains. The small atomic permanent magnets just mentioned in the last quotation from Bozorth were not found until long after we knew about crystals of iron. They just had to be invented. As previously suggested, the crystallites of a piece of steel didn't seem to furnish the close correlation needed, although their shape and size profoundly influenced its magnetic properties. Indications from theory pointed to smaller portions than the crystallites. These Bitter[2] set forth to discover. He used the old magnetic powder method, although somewhat more refined. Fine particles of red Fe_2O_3 were ground down to an average diameter of about 1μ, and then were formed into a colloidal suspension in ethyl acetate. When a drop of this suspension was put on the polished surface of a piece of steel, it was observed under a high powered microscope that the F_2O_3 particles were formed into very definite patterns, indicating small regions, each of which was magnetized to saturation in a certain direction. These regions are now called ferromagnetic domains or just magnetic domains. Bitter's original technique has been

[1] Bozorth, R. M., *Bell System Technical Jour.*, 19, 1, 1940.
[2] Bitter, F., *Phys. Rev.*, 38, 1903, 1931; 41, 507, 1932.

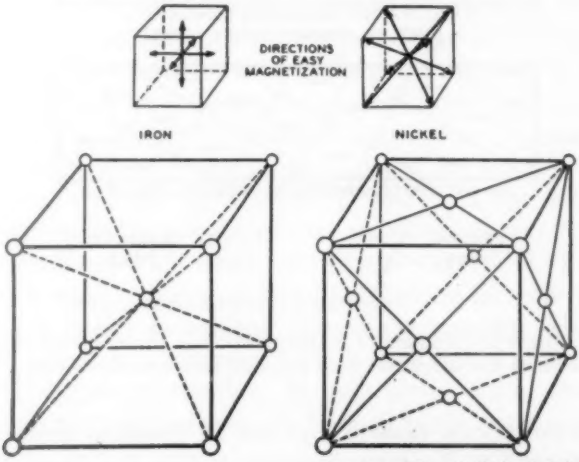
greatly improved by McKeehan and Elmore[3] and by Bozorth and Williams[4] and their co-workers at the Bell Telephone Laboratories. Fig. 57 shows some of the patterns taken from Bozorth's article in *Amer. Jour. Phys.*, 10, 73, 1942.



Courtesy of Bozorth, Bell Tel. Labs.

FIG. 57. The powder pattern produced by colloidal iron oxide on the surface of a demagnetized silicon-iron crystal, showing the presence of inhomogeneous magnetic fields. (Magnification about 1000.)

These workers agree that each domain, even in an unmagnetized piece of iron, is in a state of saturation in a direction determined by the crystal axis or the local stresses. In an unstrained condition unit



Courtesy of Bozorth, Bell Tel. Labs.

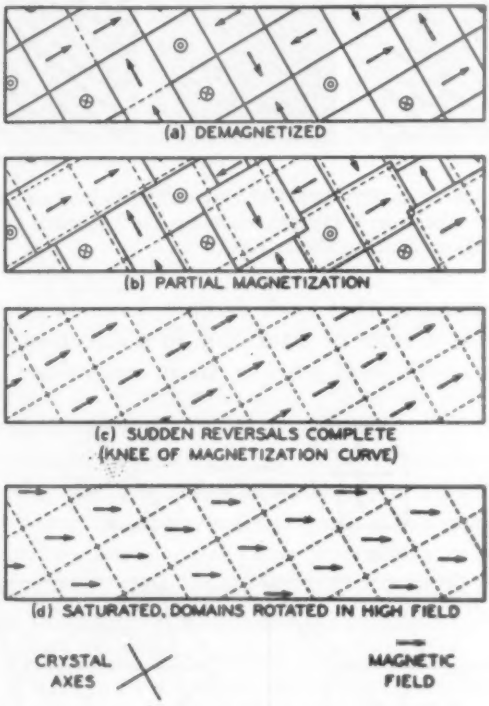
FIG. 58. The position of the atoms and the direction of easy magnetization in crystals of iron and nickel.

[3] McKeehan, L. W. and Elmore, W. C., *Phys. Rev.*, 46, 226, 1934; Elmore, W. C., 54, 1092, 1938; 62, 486, 1942.

[4] Bozorth, R. M., *Rev. Mod. Phys.*, 19, 29, 1947; Williams, H. J., *Bell Lab. Record*, 30, 385, 1952; Williams, H. J., Bozorth, R. M., and Shockley, W., *Phys. Rev.*, 75, 155, 1949.

crystals of iron, nickel and cobalt possess what are called "directions of easy magnetization." Those for iron and nickel are shown in Fig. 58. These facts about directions of easy magnetization have, of course, been learned by working with single crystals. The circles in the figures represent the positions which centers of atoms assume in an imaginary lattice such as that shown in Fig. 53.

In a piece of iron, for instance, we will have many individual crystallites in which the atoms are arranged in an orderly fashion as in Fig. 53. Within these crystallites there will again be a great many smaller regions we have already called domains, with their atoms all



Courtesy of Bozorth and Amer. Jour. of Phys.

FIG. 59. Changes in direction of magnetization in the domains of a piece of iron as the magnetic field applied, increases from zero.

arranged in an orderly fashion, but not all domains have their magnetic axes turned in the same direction within the single crystal, although the atoms are arranged in orderly fashion. They may assume, as in the case of iron, a direction which may be any one of the three ways of easy magnetization. This is shown in Fig. 59 (a) which may be taken to represent a portion of a crystal of iron. It will be noted that the three directions of the crystal axes are shown at the bottom

of the figure. The various steps portrayed in Fig. 59, a, b, c, and d, give also their relation to the various parts of the induction curve to be discussed later. It is through just such processes among the spinning electrons and the domains that we finally arrive at a fully magnetized piece of steel.

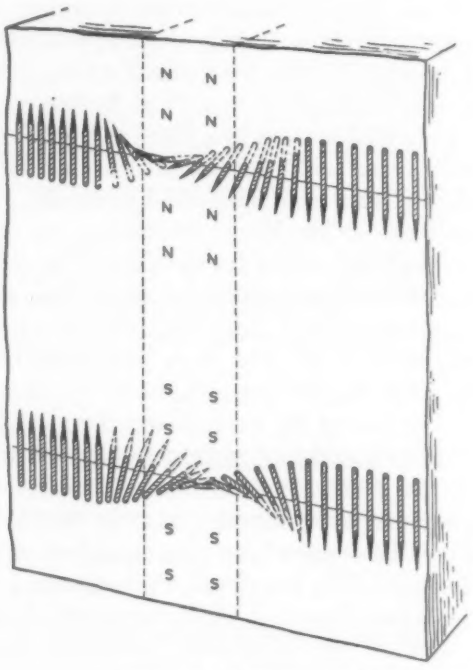
We have now discussed crystals, domains, atoms and spinning electrons. Let us stop and consider relative sizes. In 1949 Bozorth[5] gave the following data: a cubic centimeter of ordinary iron may contain about 10,000 single crystals (crystallites). A single crystal has about 100,000 domains, each with 10^{14} to 10^{15} atoms. In each of the iron atoms will be found 4 unbalanced spinning electrons. Thus in order of size come crystals, domains, atoms, and spinning electrons, which seem to be part of the mechanism which make iron, nickel, cobalt, and many of their alloys "click" as ferromagnetic substances.

Just how do they all function in a piece of iron, for example, when it is magnetized up to a point we call saturation? The domains seem to play a very important role, and the knowledge of their behavior has added greatly to our knowledge of the process of magnetization. We must understand the role of the domains. Fig. 59 (a) shows a demagnetized piece of steel. The domains are permanently magnetized in the three directions of easy magnetization, which means six directions of magnetization. In (b) Fig. 59, a field H has been applied with a very peculiar effect happening in some of the domains. Some domains increase their size at the expense of others, with the result that more of the elementary magnets appear to be orienting themselves in alignment with the field. H. J. Williams[6] has discussed this point of the moving boundaries of domains in great detail. The movements of these boundaries have even been photographed on movie strips.

As the applied field H is increased, there comes a sudden reversal of magnetization in all domains which have not already turned into that position, and all the elementary magnets are aligned along one direction of easy magnetization, as shown in (c) Fig. 59. This point is associated with what we call the "knee" of the induction curve, which will be discussed later on. Further increase in the magnetizing force finally swings the elementary magnets within the domains into complete alignment with H, and not necessarily in a direction of easy magnetization. In this latter state, shown in (d) Fig. 59, we have reached what is known as the saturation point of the specimen as a whole, although saturation had already existed in the various domains. The over-all picture is a process of aligning the elementary magnets with the direction of the applied field, but our modern knowledge of domains shows us the step by step process.

[5] Bozorth, R. M., *Bell System Tech. Jour.*, 19, 5, 1940.
[6] Williams, H. J., *Bell Lab. Record*, 30, p. 385, 1952.

The total flux, or lines of force, through the ferromagnetic body in (d) Fig. 59, will now be H, the applied field, plus the addition due to the orientation of the elementary magnets. For the present, it will suffice to say that this second addition to the flux can be represented by the term $4\pi\mathcal{J}$ where $\mathcal{J}$ is called the intensity of magnetization, and the total flux B then becomes $B=H+4\pi\mathcal{J}$, an exceedingly important equation in the building of electric machinery like dynamos, motors, transformers, etc., an equation which must have a lot of consideration before we are through.



Courtesy of H. J. Williams and Bell Lab. Record

FIG. 60. Illustrating how the electron spins orient themselves as one passes from one domain to another.

Domain Boundaries. Mention has been made of the movements of domain boundaries. These are transition regions between two domains, which are about 300 atomic layers thick. Fig. 60 shows how the axes of spin gradually change their direction from one domain to another, where the axes of spin are in the opposite direction. Midway of this boundary, which is sometimes called "Bloch Walls" for Bloch, who discovered them, the axes of spin, or tiny magnets, stand on their heads, or have their axes of spin normal to the surface. These are the

elementary magnets which seize hold of the minute Fe_2O_3 particles in the powder method for examining a polished surface of steel, and thereby outline the boundaries of the domains. As the magnetizing force is changed, these lines of Fe_2O_3 particles standing on their heads can be seen to move across the surface examined. These figures thus observed are the Bitter figures already mentioned.

Any ferromagnetic body, when brought under the influence of a magnetizing force, will go through a process much as has been described. We shall now look into this process of magnetization, and while we may think in details of crystals, domains, atoms and magnets, it will be more convenient from the overall picture to speak of magnetization as a continuous process of turning the elementary magnets in the unmagnetized condition, until they are in a complete alignment with the forces turning them.

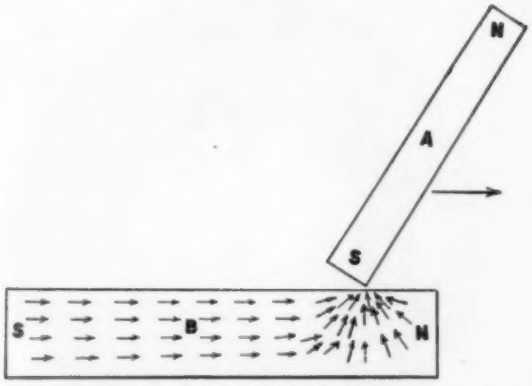


FIG. 61. Alignment of the elementary magnets in a piece of steel, *B*, as a powerful magnet, *A*, is swept along the piece of steel, *B*.

Processes of Magnetization, (a) Magnetization by Rubbing or by Contact. This was the process discussed in Chapter II in the making of artificial magnets. As one draws, let us say, the S-pole of a magnet from left to right along a piece of steel, as in Fig. 61, the domains and elementary magnets go through their paces as has just been described, giving a resultant field as in Fig. 61. If the magnet A had been a piece of magnetite and not very strong magnetically, it is quite easy to see that the resultant artificial magnet *B* would not be very strong, because the elementary magnets had not all been turned so as to be aligned with the magnetizing force from magnet *A*. In passing it should be emphasized that the mutual effects of the dipoles on each other must also help to align themselves in a common direction. However, the electrostatic force,[7] already alluded to, must be the

[7] Bozorth, R. M., *Bell System Tech. Journal*, 19, pp. 7–8, 1940.

dominant force. The degree of alignment of the elementary magnets in the magnet B will ultimately depend upon the strength of the field due to the magnet A.

(*b*) *Magnetization by a Coil of Wire.* The simplest form for showing this is in a toroid. A toroid is a ring of ferromagnetic material (iron), shaped like a doughnut on which are wound turns of wire. Fig. 62 (a) shows the completed toroid with many turns of fine wire, while 62 (b) shows in detail how the windings are made. For simplicity's sake, only one turn is going to be put around the iron core, and the radius of this turn will be so large that when it passes through

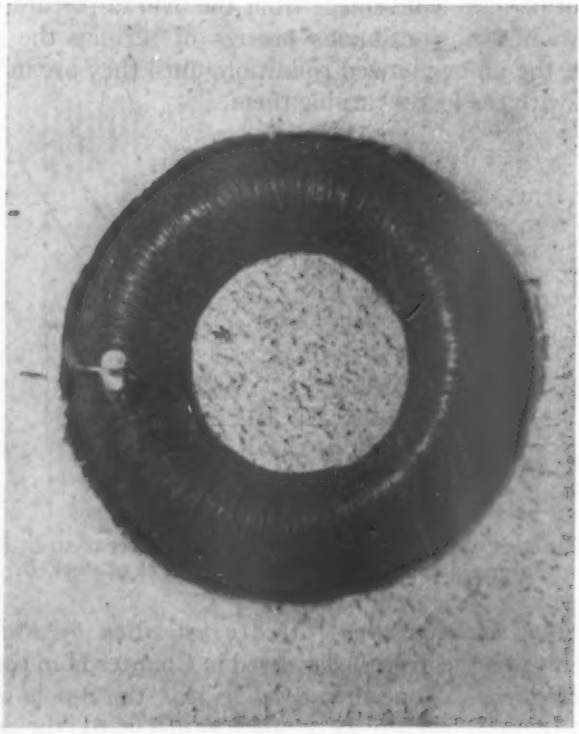


FIG. 62. (a). A toroid made from a ring of soft iron on which have been wound many turns of fine wire.

the hole in the toroid it will appear as a straight conductor, AB, in 63 (a). As the current grows in magnitude from zero on up, the magnetic field about the conductor will expand outward in ever widening circles about the wire, until it reaches the iron ring. This process was visualized in Figs. 28 and 29. When the current in the wire attains sufficient strength so that its field influences the elementary magnets in the iron ring, the first to be influenced will be those on the inner layer of iron nearest the wire, but as the current grows, successive

layers will be influenced until all of the elementary magnets have been aligned in a common direction about the ring. Figs. 63 (a) and (b) try to show how the domains exist when only the inner layer has its magnetons aligned in the proper direction. For some reason or other it seems to be generally understood that the magnetization is propagated in the direction of the field, which is wrong. It is propagated in a direction at right angles to the direction of the field. The propagation of the magnetic field in Fig. 63 (a) is radial from the wire

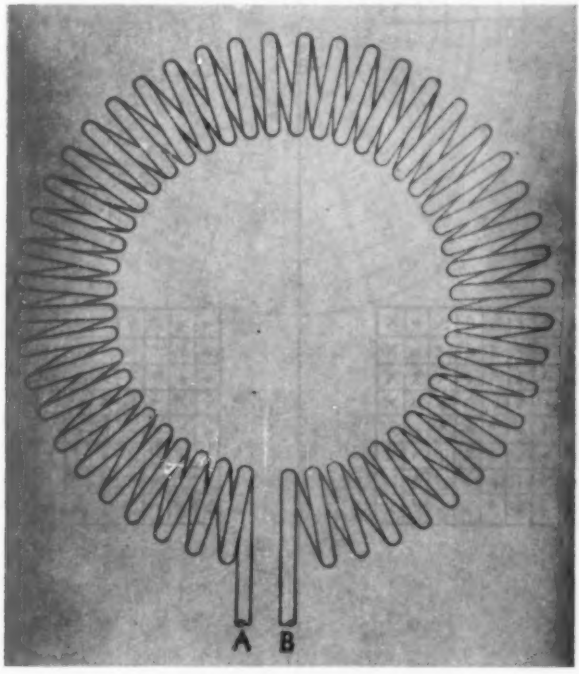


FIG. 62 (b). Showing how the turns of wire are wound on the iron ring in Fig. 62 (a).

and not around the ring. In Figs. 63 (a) and (b) the direction of the current in the wire is conventionally from A to B, so that the field in the toroid will be clockwise when viewed from above. This is indicated in Fig. 63 (b). The direction in which the magnetization progresses is that in which the energy flow takes place, and that is radially, as it does from the antenna wire of a transmitting station.

(*c*) ***Magnetization by a Long Solenoid.*** When a bar of steel is placed in a long solenoid and a current is sent through the windings, the bar of steel becomes magnetized in a direction along the axis of the bar. A solenoid may be thought of as a toroid cut at one point and straightened out. There seems to be an impression that the magnetization

runs along the bar longitudinally. Nothing of the sort occurs. It is only the direction of the resultant field which lies along the axis of the rod. The magnetic field progresses toward the iron rod radially, if it is symmetrically placed. As the field builds up it penetrates radially into the steel bar turning the elementary magnets in each successive layer until it reaches the center, where it meets the magnetization coming in from the opposite side of the rod, and the whole bar is then magnetized in a direction parallel to the axis of the bar, when a sufficiently strong field is applied.

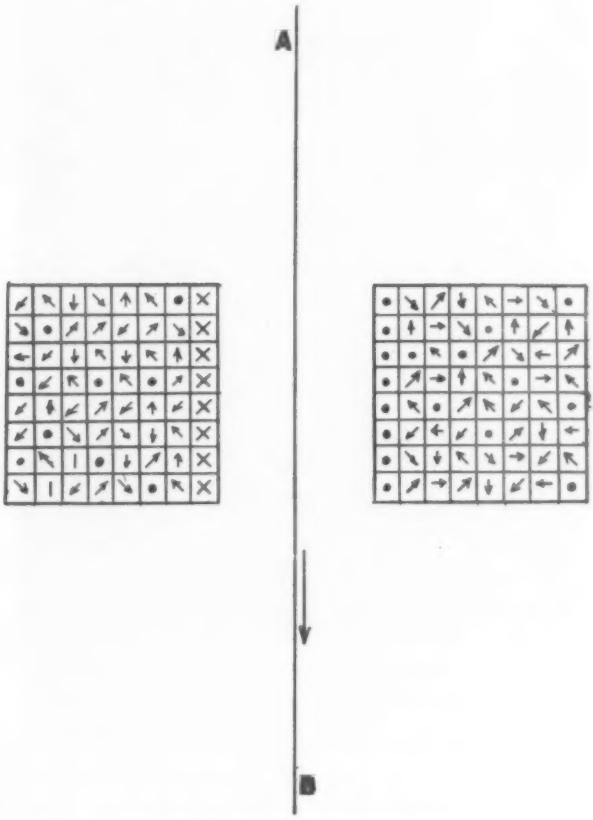


FIG. 63 (a). How the domains in an iron ring are magnetized as the magnetic field about a conductor moves out in ever widening circles about the wire.

Fig. 64 will help to visualize this process. *ABCD* is the horizontal cross-section of a bakelite tube on which hundreds of turns of wire are wound, but for simplicity, only one turn is shown, in which by means of dotted circles its magnetic field is indicated. A cylinder of iron, a section of which is *LMNP*, is symmetrically placed in the solenoid. From the drawing it can be seen that the magnetic field

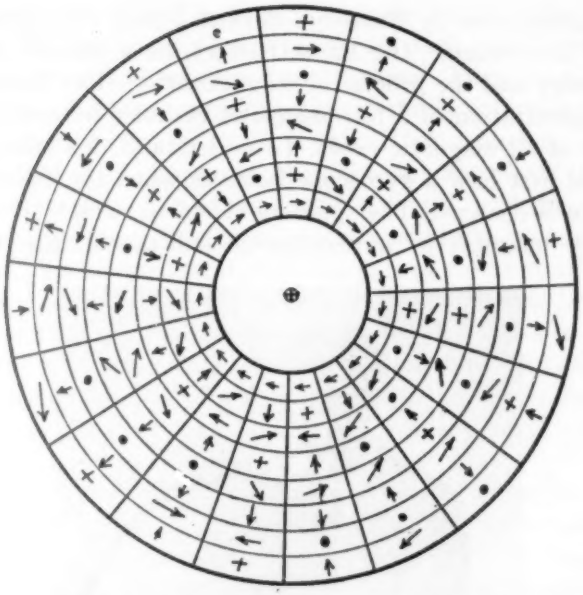


FIG. 63 (b). A cross-section at right angles to the picture shown in Fig. 63 (a).

enters the cylinder of iron radially, and penetrates toward the center, where it meets the field coming in from the other side. This will be true for all turns of a long solenoid, and so the field enters the rod radially all along the rod where the field is uniform.

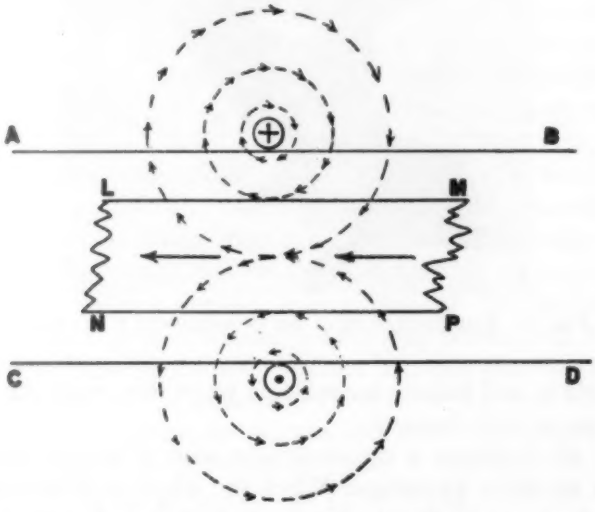


FIG. 64. When a ferromagnetic rod is magnetized in a solenoid the magnetic field moves in radially from the outside.

(*d*) *Magnetization by Rotation, Barnett Effect.* The gyromagnetic effect and its converse, the Barnett effect, have thrown much light on the theory and the process of magnetization. The Barnett[8] effect is the magnetization of a ferromagnetic cylinder by rotating it in a space free of all magnetic fields. To understand this effect we must understand first how a gyroscope behaves when the direction of its axis of spin is changed. The spinning electrons, which constitute the elementary magnets in ferromagnetic substances, are themselves

FIG. 65. Demonstration of the properties of a gyroscope.

tiny gyrostats, and behave accordingly when they have the directions of their axes of spin changed.

In Fig. 65 is shown a demonstrator with a bicycle wheel which makes an excellent gyroscope. When the wheel is set into rapid rotation, it behaves according to Newton's first law of motion in that it

[8] Barnett, S. J., *Proc. Amer. Acad. of Arts and Sciences*, 69, 119, 1934.

tries to maintain a fixed direction of the axis of spin. When it cannot do so, then the axis of spin will turn to set itself parallel to the axis about which its axis of spin has been changed. Thus, let the demonstrator set the wheel into rapid rotation in the direction shown, holding it as rigidly as possible in his hands. If an attendant whirls the demonstrator on the pivoted stool in the direction indicated for it, the axis of spin of the wheel is thereby changed, and the wheel will tend to come up over the demonstrator's head like an umbrella, so as to set its axis of spin parallel to the axis of rotation of the stool, and both stool and wheel will be rotating in the same direction. If the demonstrator sets the wheel spinning in the opposite direction, but the attendant still rotates the stool in the same direction as before, the wheel tends to turn downward, so that again both wheel and stool will have their axes parallel and rotating in the same direction.

This is what Barnett found that the spinning electrons in a cylinder of iron, or other ferromagnetic body, would do. They would all turn to set their axes of spin parallel to the direction of rotation of the iron cylinder and in the same direction of rotation. In other words, the cylinder became magnetized by the simple process of rotation. This behavior also confirmed the idea that to give the direction of magnetization observed in the iron cylinder, it was necessary for negative charges to be spinning, thus confirming the proposition that the magneton is a spinning, negative, electric charge, viz., the negative electron.

It is interesting to consider how the domains, elementary magnets and other units behaved in the process of rotation. Inasmuch as the force tended to set the axes of spin parallel to the axis of rotation of the cylinder, one would be led to believe the process would be much the same as when a magnetizing force is applied longitudinally to the cylinder.

In the gyromagnetic effect, on the other hand, a ferromagnetic cylinder is suspended by a fine fiber which is a continuation of the axis of the cylinder. About the cylinder are wound many turns of wire, so that cylinder and coil form a solenoid with, let us say, an iron core. When an electric current is sent through the coil, all of the spinning electrons in the cylinder, whose axes point in all directions, suddenly have their axes of spin thrown into one common direction, and all with spins in the same directions. In order that the angular momentum of the system be maintained zero, the cylinder of iron will tend to rotate in a direction opposite to the direction in which the negative electrons are spinning. Thus in Fig. 65, if the operator sets the bicycle wheel rotating in the direction of the arrow as indicated and raises the wheel over his head like an umbrella, the operator

and stool will begin to rotate in a direction opposite that in which the wheel is rotating.

Scott[9] has given a simple derivation of the equation which gives the value of the so-called gyromagnetic ratio g'. For iron, Scott finds a value

$$g' = 1.0278 \pm 0.0014 \; m/e$$

wherein g' turns out to be nearly the same as the ratio between the mass of the electron and its elementary charge.

By microwave technique the value of the gyromagnetic ratio g turns out to be a value different from g' as found by the method Barnett, Scott and others have used. Why this is true needs further research.

One cannot overemphasize the importance of the two gyromagnetic effects which have now been discussed. It has given a knockout blow to any lingering conception that in the process of magnetization something flows. The school of translation has received some other rather hard jolts in recent experiments.

In the early days of the knowledge of magnetic phenomena, it was taught by the school of translation that when a piece of iron, for example, was magnetized, something either flowed into it or out of it, thereby changing its weight. One hundred and fifty years ago, Cavallo[10] spoke definitely of iron losing in weight when magnetized. As late as forty years ago Bauer[11] showed a difference in weight for a steel bar between the magnetized and unmagnetized state, but no definite answer came out of the work. Recently this experiment was repeated,[12] using a non-magnetic balance in a space free from all magnetic fields, at least reduced to fields less than 2γ, where $\gamma = 10^{-5}$ oersted. Working under these ideal conditions it was shown that to one part in 3 million there was no change in the weight of a piece of iron when magnetized. One must conclude that those who in the past found a difference in weight between the magnetized and unmagnetized piece of iron, were working where a vertical field gradient of one kind or another existed. Such a gradient would give a difference in weight between the two conditions, magnetized and unmagnetized, when the magnet was weighed, standing on end.

Another experiment has been tried recently which was based on the idea that something flows when a piece of iron is magnetized. It was wrongly assumed that the process of magnetization of the core of a toroid progressed around the iron ring instead of entering it

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[9] Scott, C. G., *Phys. Rev.*, 82, pp. 542–547, 1951.

[10] Cavallo, Tiberius, "A Treatise on Magnetism in Theory and Practice." 3d Ed., p. 75, 1800

[11] Bauer, L. A., *Terr. Mag. and Atmos. Elec.*, Vol. 12, p. 25, 1908. Vol. 14, p. 72, 1909.

[12] Williams, S. R., SCHOOL SCIENCE AND MATHEMATICS, p. 433, June, 1951.

radially as was shown some pages back in this chapter. The experiment was carried out in the following way: a toroid was carefully built, see Fig. 62 (a), with respect to its symmetry, and then suspended on a fiber coincident with the axis of the toroid. The electric current was carried in and out by fibers, as in the case of a d'Arsonval galvanometer coil. In bringing the iron core to a point of saturation, it was assumed that something would flow around the iron ring of the toroid, and in this flow there would be a reaction which would

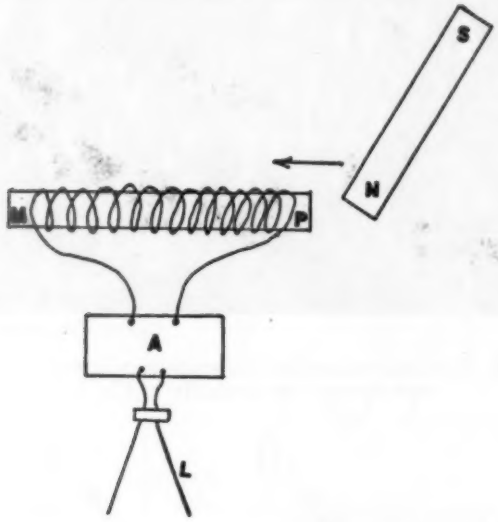


FIG. 66. Arrangement for demonstrating the Barkhausen Effect.

FIG. 67. An oscillographic record of the Barkhausen effect with timing record adjacent.

give a ballistic throw in the opposite direction to the toroid suspended on a fine fiber. No such effect could be found, although the energy involved would have been sufficient to have given the toroid a large throw. This experiment certainly proved that there is no flow of "something" in the direction of magnetization. If anything flows it must be at right angles to the direction of magnetization.

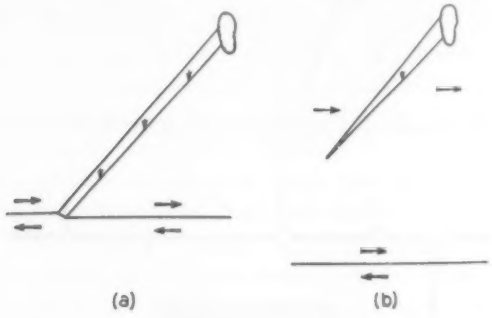
From all of the experiments which have been cited, it becomes quite clear that the process of magnetization consists in the orienta-

tion of the elementary magnets within the medium, and not in the flow of "something."

The Barkhausen Effect and Domains. In 1919 Barkhausen[13] published an account of a new effect which has been called the Barkhausen effect ever since. It may be observed in the following way: a thin piece of soft iron MP forms the core to a coil of many turns of fine wire, Fig. 66. The terminals of the coil are connected to an amplifier, A, which feeds into a loud speaker, L. When a magnet, N-S,

Courtesy of Bozorth in Bell Tel. Record.

FIG. 68. Photomicrograph of the secondary domain boundary represented schematically in Fig. 69.



Courtesy of Bozorth in Bell Tel. Record.

FIG. 69. A secondary domain boundary forms at a crystal imperfection, as indicated in (a); when the applied field is increased, and the main boundary moves, the secondary boundary stretches until it finally snaps off, as shown in (b).

approaches or recedes from the piece of iron, MP, a murmering is heard from the loud speaker, indicating that the process of magnetization of the iron strip by the magnet is not a continuous one, but proceeds by jumps. When drawn out on an oscillographic record it appears as in Fig. 67. At the Bell Telephone Laboratories,[14] they have

[13] Barkhausen, *Physikal Zeitsch.*, 20, p. 401, 1919.

[14] Williams, H. J. and W Shockley, *Phys. Rev.*, 75, p. 170, 1949; Williams, H. J., *Bell Labs. Record*, 30, p. 390, 1952.

been able to not only hear this murmering sound but at the same time observe the movements of the domain boundaries. There are in crystals of iron, spike-like domains that form at crystal imperfections. Such a domain is shown in Figs. 68 and 69. When the boundary (a), Fig. 69, moves away from this spike-like domain as shown at (b), the spike-like domain stretches and finally snaps off as shown. It is these jumps when the spike-like domains snap that give rise to a part of the Barkhausen effect. Not only can the Barkhausen noise be heard through the loud speaker, but simultaneously the movements of the domain boundaries visually observed under a microscope. It is when these sudden breaks occur that a loud click is heard in the Barkhausen effect, giving definite information that not every Barkhausen pulse is necessarily due to a reversal of an entire domain as we have taken for granted heretofore, although such a reversal does add to the Barkhausen effect.

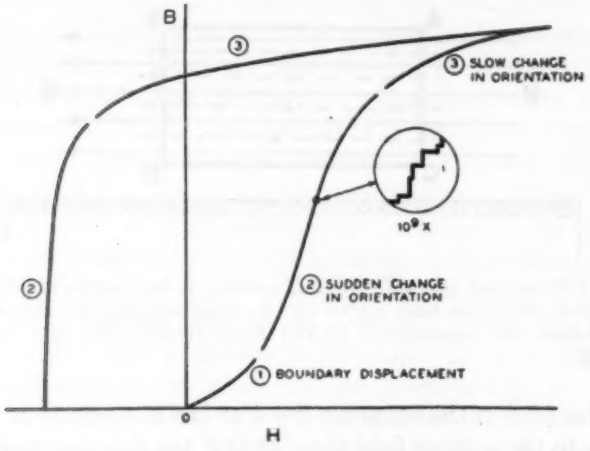


FIG. 70. A curve showing the relations between B and H. The small inset shows that the curve is not a smooth one, but made up of irregular increments represented by the Barkhausen discontinuities.

The Significance of the Equation, $B=H+4\pi\mathcal{I}$. If one measures the magnetic flux B, i.e., the number which represents how many lines of force thread through a unit area in a medium which is being magnetized, and compares this number with the field strength being applied, there will result what is known as a normal induction curve. It was shown in Chapter II that the ratio of $B/H=\mu$, a ratio which is called the permeability factor. In Chapter III the magnetic field inside of a solenoid was given when the core of the coil was air, or better, a vacuum. When the solenoid has an iron core, then the flux, or lines of magnetic force through it, is no longer $H=4\pi nC$, but $B=4\pi\mu nC$, wherein

$$\frac{B}{H}=\frac{4\pi\mu nC}{4\pi nC}=\mu.$$

μ, however, is not a constant, but varies with the field applied, and therefore B is not directly proportional to H. The determination of B is one of the important items, then, when it comes to selecting the material which goes into transformers, dynamos and motors where production of large magnetic fields is desired. If inside a solenoid one places a core of soft iron, for example, and by a method to be described later one measures the values of B as H increases up to and beyond the point we call the point of saturation, the curve obtained by plotting the relation between B and H will be one like that shown in 0, 1, 2, 3, Fig. 70. It is known as a normal magnetization curve.

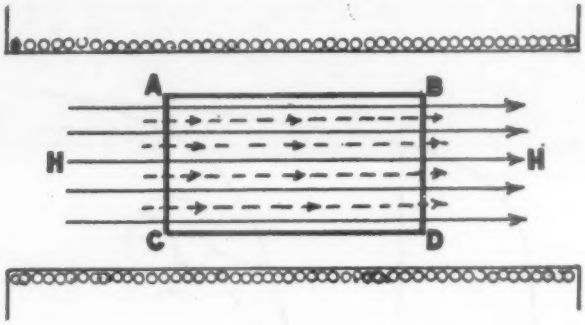


FIG. 71. The applied magnetic field, $H=4\pi nC$, is represented by the long continuous arrows, while the lines added by the orientation of the elementary magnets, $4\pi\mathcal{J}=4\pi m'$ are represented by the short arrows. The sum of the two is $B=H+4\pi\mathcal{J}$.

The value of B in the equation $B=H=4\pi\mathcal{J}$ is made up of two parts, (1) H, due to the applied field plus (2) $4\pi\mathcal{J}$, the flux due to the turning of the elementary magnets into alignment with H. All of the terms in this last equation represent the number of lines of magnetic force per unit area. The quantity $\mathcal{J}$ is what is called the intensity of magnetization. It arises in this way: in Chapter II it was shown that $4\pi\ m$ lines of force radiate from a positive pole of strength m. When a cylinder of iron, for example, is placed inside of a solenoid where the field is constant, Fig. 71, there will emanate from the positive pole not only H lines of force per unit area due to the field applied, but there will also be, right close to the positive pole, $4\pi\ m$ lines of force emanating from the end of the iron cylinder per unit area where m is now the pole strength per unit area. This extra field has all arisen from the elementary magnets within the iron turning their individual fields so as to augment the field H applied. But the pole strength per unit area, is the way in which we speak of the intensity

of magnetization of a substance, and is a measure of the way the applied field has been effective in turning the elementary magnets within the specimen. It tells us more specifically about the substance, its magnetic quality, for instance, than does B, which, as just shown, is made up of two factors. Hence we may write:

$$B = H + 4\pi m = H + 4\pi \mathcal{J}$$

$$\mathcal{J} = m$$

This equation will be discussed in greater detail in a succeeding chapter.

Relation of Domains to the Induction Curve. A brief outline has already been given in this chapter of the way in which the domains behave until the point of saturation has been reached, or that condition where all the elementary magnets have been aligned as nearly parallel as they can be made with the applied field. Now we want to know the specific relations between these various conditions of the domains and the various values of B produced. In passing through the different steps by which the domains operate as the applied field advances from zero up to the point of saturation, every value of B has been attained. When these values of B are plotted with respect to H, a so-called induction curve is obtained. This was shown in the line 0, 1, 2 and 3 Fig. 70, which represents such a normal induction curve, and on that curve are shown what parts are due to the various processes in the domains as the field is increased. By ordinary methods for finding the values of B for corresponding values of H, the resultant curve when plotted appears as a smooth curve. By proper instruments[15] this curve is shown to be made up of many irregular jumps as indicated by the small circular insert in Fig. 70. These are due to the so-called Barkhausen discontinuities, which are produced by reversal of domains and by the snapping of the spike-like domains in the neighborhood of structure irregularities in the ferromagnetic substance.

Magnetic Susceptibility. If one divides the equation

$$B = H + 4\pi \mathcal{J}$$

by H, the equation

$$\mu = 1 + 4\pi K,$$

emerges in which we recognize our old friend, μ, the factor of permeability. K is a new conception, and represents the ratio

$$\frac{\mathcal{J}}{H} = K$$

[15] *Bell Lab. Record*, p. 247, June 1952.

which is a measure of how many elementary magnets have been aligned with H. It is called the factor of susceptibility, which, like $\mathcal{I}$ tells us more specifically the magnetic quality of the substance being investigated. When K is small for a piece of iron, we know that not many elementary magnets are being aligned, and therefore not a good material for dynamo and motor pole pieces, or for transformer cores.

In succeeding chapters it will be seen how important a role K plays in the theory of magnetization.

SCIENCE AND ARITHMETIC IN THE FIFTH GRADE

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Where can we find a better opportunity to integrate the teaching of subject matter than in Science and Mathematics? Is there any area in the field of science that is not based squarely and solidly on quantitative and qualitative concepts together with laws that operate in space and time? As for mathematics, is there any part of it that is not a science? How can it be separated from the laws of nature, of motion, power, energy, sound, light, etc., which we know as science?

The word integration has been an interesting one to me for some time. I've been thinking about it a lot in connection with the ever growing number of projects, responsibilities and challenges superimposed upon classroom teachers. Not long ago I worked with a small group of teachers, kindergarten through senior high school, who had chosen the area of *integration* for study in connection with the development of a curriculum guide. The word integration with its various shades of meaning intrigued me. It seemed to offer a way out from so many of the pressures we are under.

The dictionary defines the word integration as "the act or process of making whole or entire; the formation of a whole from constituent parts": In mathematics it is the "inverse of differentiation." Why should we go on offering a little block of subject matter known as arithmetic at one time of the day and another little block at another time called science? If we pursue this subject of integration far enough we can actually reduce all of our teaching to the three great areas of reading, writing and arithmetic. That, however, is another matter and requires another paper to deal with it adequately.

Take the subject of weather. Where can you find a fifth grade classroom nowadays that doesn't have a unit on weather?

Jimmie and Parris kept our weather records last year. Every day they gave the weather report. "Temperature this morning twenty-

eight degrees. High today forty-eight. Low tonight twenty; high tomorrow forty-five. Temperature change today twenty degrees. Temperature change tomorrow twenty-five. Five degrees difference in amount of change expected between today's readings and tomorrow."

They gave us also the high and low readings for cities listed on the weather maps in the daily paper. What an excellent opportunity to become experts in rapid subtraction. The following arithmetic lessons worked out in our classroom will illustrate what can be done in a study of temperature changes alone.

LET'S FIGURE THE WEATHER

What is the temperature today;
Too cold to go outdoors to play?
Oh, no, I'll bundle up quite warm
And play outside all safe from harm.

The weather really does have a lot to do with our every day activities. If it's very, very cold we put on warmer clothes and more of them. Mittens, scarves, galoshes and warm underwear. Then we may face the cold with sparkling eyes and rosy cheeks. We enjoy running fast, sliding, skating or skimming down the hillside on a pair of skis. If on the other hand, it is very, very hot we wish to take off as many clothes as possible. Sometimes boys and girls like to play about their homes with bathing suits on. They may turn on the lawn hose and run in and out under the water. Girls wear thin dresses or sun suits. Boys wear slacks and T shirts. Older folks wish to sit quietly in the shade or turn on their electric fans.

Did you hear the weather report today? What was the temperature when you dressed for school? Did you dress suitably for today's weather? How do you decide what to put on? Do you need different garments for every degree of change in temperature or do you count by 5 degrees, 10 degrees, etc., in deciding what to wear?

Readings on February 15, 1953 as shown in the daily paper:

SATURDAY TEMPERATURES

2 A.M. 21	11 A.M. 20	10 P.M. 5
3 A.M. 22	Noon 21	11 P.M. 4
4 A.M. 27	1 P.M. 22	Midnight 3
5 A.M. 25	2 P.M. 21	
6 A.M. 22	3 P.M. 20	Sunday
7 A.M. 19	4 P.M. 19	1 A.M. 3
8 A.M. 19	5 P.M. 16	
9 A.M. 20	6 P.M. 13	
10 A.M. 20	7 P.M. 10	
	8 P.M. 7	
	9 P.M. 6	

1. About what time last Saturday morning did you get up? What

was the temperature at that time?

2. How many hours was that before noon?

3. What was the temperature at noon?

4. How many degrees did the temperature change during the morning hours?

5. Would you consider that enough of a temperature change to put on or take off any clothing?

6. How many hours was it from noon until the time you went to bed?

7. How many degrees did the temperature change during those hours?

8. How many hours were you awake on Saturday? Did the temperature get colder or warmer during those hours?

9. How much of a change was there between the lowest temperature and the highest during your waking hours on Saturday?

10. Make a bar graph to show the hourly temperature changes during the hours you were awake on Saturday.

PROBLEMS

1. The temperature at 2 A.M. on Saturday, Feb. 15, 1953, was _____. At noon it was_____. How much difference was there?

2. What was the highest temperature during the morning hours? _____

3. What was the lowest temperature during the morning hours? _____

4. What was the difference between the highest and the lowest temperatures during the morning hours?

5. The temperature at 6 o'clock P.M. on Saturday was_____. Was that lower or higher than the temperature at noon? How much?

6. The temperature at midnight was_____. Did the temperature go up or down during that time? How much?

7. From 2 A.M. until 2 P.M. is how many hours?

8. Through how many degrees did the mercury in the thermometer move during those hours on Saturday?

9. From 8 A.M. until 6 P.M. is how many hours?

10. What was the highest temperature and the lowest temperature during those hours on Saturday?

See next page

1. In what section of the U.S. would you expect to find the highest temperature?

2. Two cities in the U.S. had high temperature of 74°. What were they? Locate them on the map.

TEMPERATURES IN CITIES OF THE U.S.

SATURDAY, FEBRUARY 15

GENERAL OBSERVATIONS

EAST CENTRAL

	A	B	C		A	B	C
Chicago	45	32		Indianap.	50	28	
Cincinnati	48	25		Madison	35	28	T
Cleveland	47	27		Marquette	31	23	T
Detroit	48	30		Milwaukee	39	29	
Escanaba	32	13	T	S.S. Marie	34	22	T
Gr. Rapids	42	30	T	Traverse Cy	38	25	.06
Green Bay	32	18					

WEST CENTRAL

Des Moines	35	30		Okla. City	52	39	.02
Dubuque	33	23		Omaha	38	30	.01
Kan. City	46	33	103	St. Louis	50	31	
Little Rock	49	33	.01	Sioux City	34	27	.01

ATLANTIC

Atlanta	51	31	.26	New York	47	33	
Boston	43	28		Philadelphia	48	28	
Jacksonville	65	36		Pittsburgh	47	26	
Miami	74	58		Washington	50	37	

GULF

Abilene	56	39		N. Orleans	55	49	1.36
Brownsville	72	52		S. Antonio	63	57	.14
El Paso	61	32		Tampa	74	44	

MOUNTAIN

Albuquerque	49	27		Phoenix	68	36	
Boise	53	28		Pueblo	46	18	
Cheyenne	35	7	.14	S. L. City	44	25	
Denver	44	20	.06	Tucson	66	35	
Helena	33	21					

PACIFIC

Fresno	69	35		Seattle	48	36	T
Portland	54	43	.06	Spokane	42	31	.08
San Diego	64	46		Yuma	74	42	
S. Francisco	59	40					

CANADA

Pt. Arthur	21	10		Regina	9	−2	
Edmonton	28	8		Winnipeg	5	−4	.01
Calgary	35	9					

A—Highest temperature Saturday
B—Lowest temperature Saturday.
C—Precipitation.
T—Trace.

3. Which of the two cities had the greater change of temperature? How much greater?

4. The high and low for the Twin Cities area on Saturday was _____and_____. What was the range?

5. What was the change of temperature on Saturday, February 15 in the following cities?

Chicago	Cheyenne
St. Louis	San Francisco
New York	Winnipeg, Canada

6. In which of the above cities was the change of temperature the greatest?

7. Find the difference between the highest and the lowest temperatures in each of the cities of the East Central Section.

8. Make a bar graph to show the change of temperature in the following three Pacific coast cities: Portland, San Francisco and San Diego.

9. At 8 o'clock the temperature in Minneapolis was 19°. In Tampa, Florida it was 74° at the same hour. What was the difference? Tell how you would dress in each place.

10. Locate Brownsville, Texas on the map. The temperature in Brownsville was 72° while that in Regina, Canada was 9°. What was the difference in their temperatures? What differences should be made in dressing for these different weather conditions?

This is just a beginning. Daily reports of temperature changes in cities throughout the United States will yield highly motivated practice exercises in addition and subtraction. Experiences with signed numbers, plus and minus numbers, comes when we figure above zero and below zero readings—and plot graphs for temperature changes during a twenty-four hour period, for a month, a year, for cities in different sections of the U.S. etc.

Many arithmetic experiences may be provided by noting and keeping records of wind direction changes. One type that has proved its usefulness in my class is the following:

What are the prevailing Winds for this Section? At the end of the month the following summary was drawn from the daily weather reports kept by the children.

N.W. winds_____	N.E. winds_____
West winds_____	E. winds_____
S.W. winds_____	S.E. winds_____
Total westerly winds_____	Total easterly winds_____

The prevailing winds for the month of_____ were_____

_____

When this record is kept faithfully over a period of months the

class has learned from actual mathematical experience that the prevailing winds for our section is westerly.

Wind velocity records yield additional mathematical reckoning.

When the wind has a velocity of less than one mile per hour the trees are quiet and smoke rises vertically from the chimneys and the wind is said to be *calm*.

When the wind is *light*, the velocity is 4 to 7 miles per hour, the wind may be felt on the cheek, the leaves rustle and the wind vane moves. Winds said to be *moderate* are those moving 13 to 18 mile per hour, loose paper and dust is blown about and small tree branches move. *Fresh* winds blow from 28 to 31 miles per hour, large tree branches move and it is difficult to carry an umbrella.

Strong winds, those which blow from 39 to 46 miles per hour break twigs from the trees and make walking difficult.

When the wind is blowing from 55 to 63 miles per hour it is said to be a *gale*, trees are uprooted and blown down.

Hurricane winds blowing more than 75 miles per hour do a great deal of damage. Fortunately they are not experienced very often.

Watching the barometer, making several kinds of simple barometers, keeping records of changes in air pressure and predicting weather changes from the speed and amount of pressure changes are activities that should yield their toll of arithmetic learnings as well as science experiences.

Records of precipitation lead into simple experiences with decimal tenths and hundredths while sunshine records yield percentages.

In the May 1953 issue of SCHOOL SCIENCE AND MATHEMATICS an article by Maitland Simmons entitled "Science at Work," shows in the unit of Simple Machines the complete and natural integration of Science and Mathematics. Why do we not save ourselves time, energy, textbook money and needless pressures by exploring the possibilities here indicated?

Color filter permits amateur photographers to take better color pictures in almost any kind of weather. By giving him control of the "color balance" of the picture, the adjustable filter also extends the daylight hours through which he can make better color shots.

Color control meter, made by the same company, is designed for use with the new filter and for standard color correction filters. The meter measures the balance of red and blue in natural light and indicates the proper filter for the picture. The meter shows the photographer how to exaggerate colors for special effects, or how to correct them for better results.

Suspenders now are being made "extra-wide" with built-in pockets for carrying combs and nail files. Their faille weave is strengthened with rayon, and the pocket flaps are made of kid leather.

BETTER LABORATORY WATER FOR LESS

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The Problem and a Possible Solution

High school chemistry instructors need pure water for laboratory purposes and desire to obtain this water as cheaply as possible. Of course, tap water may be satisfactory for many experiments, but qualitative chemistry necessitates the use of water of high purity. Although the average high school laboratory course does not involve extensive work of an analytical nature, it is consistent with the best techniques of chemical procedure that the student be taught the value of excluding all possible side reactions. Only thus can a full understanding of the controlled experiment be gained and effects attributed with certainty to the known factors. Moreover, abstention in the use of tap water as a reactionary medium provides more adequate preparation of the college-bound student. An appreciation of the value of pure reagents and for the necessity of clean equipment should be objectives in any chemistry laboratory course.

Distillation is the conventional procedure for obtaining pure water. Hence, the high school laboratory must be equipped with distilling apparatus or must satisfy its distilled water needs by purchase from an outside source. Distilled water is relatively expensive whether purchased or processed. To understand why this is true, imagine having 999,860 pure white marbles mixed with 140 black ones. These black marbles represent 140 parts per million of the mixture. If it became essential to remove the black marbles from the mixture with a minimum expenditure of effort, should the 999,860 white marbles be taken away from the 140 black marbles, or vice versa? Distilling tap water to remove 140 ppm of impurities is a case of taking 999,860 parts away from the original million. Deionization is more direct; it will remove the 140 ppm of impurities from the original million parts of tap water.

Deionization of tap water offers a means for obtaining water of an electrolytic purity comparable with—and, in many instances, superior to—distilled water. Furthermore, the cost of equipment may be less than that of a distiller; installation is more simple and less expensive; a source of heat and a continuous flow of water are not necessary; and the rate of production is five or more gallons per hour. When adjusted properly, deionization apparatus purifies all of the water flowing through it and produces water comparable with that produced by single distillation. Purities equal to that produced by triple distillation may be obtained for a small additional expense. An additional

advantage of deionization is that the process has many industrial applications. Deionization is but one application of ion exchange, and ion exchange has become important enough to warrant at least a brief discussion in the classroom, perhaps during the study of a unit on ionization. If the laboratory water used by the student is purified by ion exchange, what better motivation can be desired for the study of the theory of ion exchange, the methods used, and the industrial applications of the process?

What Are Ion Exchangers?

In 1935 two English scientists, Adams and Holmes, discovered that synthetic organic resins possess ion exchange properties.[1] This discovery opened the way for the purification of water by chemical means. Synthetic resins were found to be superior to the carbonaceous exchangers used previously because they have very high efficiencies and capacities. Therefore, chemical deionization of tap water is rapidly replacing conventional distillation in many industries.

An ion exchanger is a complex organic compound possessing a loosely held ion which is capable of being exchanged for a different ion. Ion exchangers are of two kinds. Those ion exchangers which have a loosely held positive ion are called cation exchangers; those possessing loosely held negative ions are called anion exchangers. Acid adsorbent (or absorbent) resins are also called "anion exchangers," but this is a misnomer, for such resins absorb acid molecules in solution without an exchange of ions.

The advantages of synthetic resin exchangers which are of primary concern for high school use are:

1. They possess high chemical and mechanical stability.
2. They can be used longer before the necessity occurs for regenerating or discarding the exchange bed.
3. They have uniform chemical and physical quality.
4. The rate of flow through the exchangers can be maintained at a greater velocity due to a high rate of exchange.
5. The purified water will continue to have a high degree of purity until the bed is exhausted.

What Is Meant by the Deionization of Tap Water?

According to Kunin and Meyers,[2] desalting, deashing, and demineralizing are sometimes used as though they are synonymous with deionizing, but this is incorrect because they are more restrictive in meaning. When we deionize water we remove all charged particles.

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[1] "Ion Exchange." *Rohm & Haas Reporter* (March, 1950), 4.

[2] Kunin, R. and Meyers, R. J., *Ion Exchange Resins*. New York, John Wiley & Sons, Inc., 1950, p. 88.

This includes not only ions but the positively or negatively charged particles comprising a colloidal dispersion. All of the impurities present in tap water are not ionic in nature nor inorganic salts by composition. Thus, deionized water may be as pure, or more pure, than distilled water from the standpoint of ionic content, but its purity may be less than that of distilled water in other aspects. Its purity with reference to neutral particles will be little improved over that of the influent tap water. However, tap water usually contains only negligible amounts of such impurities. Therefore, the inability of ion exchangers to remove such impurities can be disregarded for the purpose under discussion. The electrical conductivity of deionized water is less than that of distilled water. It is safe to conclude that deionized water is eminently satisfactory in its ability to meet the requirements of the high school laboratory. To summarize, we may define tap water deionizers as ion exchangers capable of exchanging only hydrogen and hydroxyl ions for those ions present in tap water.

Deionization Methods

There are three methods for deionizing electrolytic solutions such as tap water. The terminology used in this paper is the same as that used by Kunin and Meyers,[3] namely, the "conventional," the "reverse," and the "mixed bed" (monobed) methods.

I. *The Conventional Method*

The influent tap water passes first through a sulfonic acid cation exchanger resin. This is the *hydrogen cycle* for which only organic cation exchangers are used. This may be illustrated in equation form by letting HR represent the strong-acid resin R-SO_3-H, where R is the core of the resin, as follows:

$$HR + M^+ + X^- \rightarrow MR + H^+ + X^-$$

In the above reaction M^+ represents any positive ion and X^- represents any negative ion. Note that a salt is reacting with the hydrogen exchanger by metathesis to form an acid. Specific reactions for calcium sulfate and calcium bicarbonate would be:

$$2HR + Ca^{++} + SO_4^{--} \rightarrow CaR_2 + 2H^+ + SO_4^{--}$$

$$2HR + Ca^{++} + 2HCO_3^- \rightarrow CaR_2 + 2H_2O + 2CO_2$$

It should be noted that all ionic exchange reactions are reversible with the shift of the point of dynamic equilibrium occurring in accordance with the Law of Mass Action. Therefore, the degree of reversibility of the above bicarbonate reaction is negligible because the

[3] *Ibid.*

calcium ion is removed from solution and the bicarbonate ion is destroyed. The effluent water could be degasified to remove the dissolved carbon dioxide, but this would probably be unnecessary when the water is to be used in a high school laboratory.

At the conclusion of the hydrogen cycle, the cation exchanger effluent is passed through a weak-base anion exchanger. There is a difference of opinion as to the exact mechanism of the changes that occur during this cycle. Some authorities maintain that the action is one of absorption while others support their contention that actual ionic exchange occurs. Suppose that for compromise purposes we settle for this statement from Nachod:[4] "Heymann and O'Donnell conclude that in aqueous solution the two processes cannot be distinguished." As a result of this difference of opinion, two different schematic representations are used in the literature to depict what happens during the anion exchange cycle. The first of these is used to represent the action of a resin capable of exchanging hydroxyl ions for anions originally present in the tap water. ROH is used to represent the exchanger.

A. *Removal by ion exchange*

$$ROH + H^+ + X^- \rightarrow RX + HOH$$

Thus, for sulfuric acid:

$$2ROH + 2H^+ + SO_4^{--} \rightarrow R_2SO_4 + 2HOH$$

The second schematic representation involves the action of a resin which functions by absorbing (or adsorbing) both of the ions of either an organic or inorganic acid. This, of course, is not truly a case of ion exchange. RN is used to designate a resin of this type.

B. *Removal by adsorption*

$$RN + H^+ + X^- \rightarrow RN \cdot HX$$

Thus, for sulfuric acid:

$$2RN + 2H^+ + SO_4^{--} \rightarrow (RN)_2 \cdot H_2SO_4$$

In both of the above cases, the effluent water emerges from the resin bed devoid of cations and anions; i.e., the influent tap water has been deionized.

II. *The Reverse Method*

The chemical reactions occurring in the reverse method are very similar to those of the conventional method. The distinguishing feature is that the anions are removed first by a strong-base anion ex-

[4] Nachod, F. C., *Ion Exchange—Theory and Application*. New York, Academic Press Inc., 1949, p. 25.

change resin followed by cation removal by a weak-acid exchanger.

A. *Anion exchange cycle of an R_4N-OH resin, designated ROH*

$$2ROH + Ca^{++} + SO_4^{--} \rightarrow R_2SO_4 + Ca^{++} + 2OH^-$$

B. *Hydrogen cycle of an R-COOH resin, designated HR*

$$2HR + Ca^{++} + 2OH^- \rightarrow CaR + 2HOH$$

The reverse method is particularly useful in industrial applications where the pH must be kept in the alkaline range. The *Rohm & Haas Reporter*[5] states: "Reverse Deionization is necessary if organic solutions sensitive to the acid produced in a cation exchanger are to be treated."

III. *The Mixed Bed or Mono-Bed Method*

The exchangers of a mixed bed function chemically in the same manner as the exchangers used in the multiple bed methods. The main difference is that the exchangers are intimately mixed in a single bed, and, therefore, the reactions may occur either "conventionally" or in "reverse." If an anion is exchanged first, the reaction will be followed momentarily by a cation exchange, and vice versa. This makes possible a much more rapid rate of exchange, so water can be purified at a more rapid rate. Moreover, the degree of purity is usually superior to that obtained by the two methods previously discussed. This contention is supported by a booklet printed by The Resinous Products Division of Rohm & Haas Company:[6] "Although both methods (single bed and two-bed systems) yield water of exceptionally high quality, the single bed system known as MONO-BED, can produce water of somewhat higher quality than the two-unit system." This is because a strong-acid cation exchanger is used with a strong base exchanger, allowing the reactions to proceed at a neutral pH.

The mono-bed method has one distinct disadvantage. Strong-acid and strong-base exchangers are more difficult to regenerate because the acids and bases used in regeneration must be stronger. Moreover, regeneration is especially difficult because the exchangers must be separated before it is possible to regenerate them without destruction. In industry this is usually done by hydraulic separation—the exchangers have different densities. Since hydraulic separation is not practical for high schools, mono-bed resins must be regenerated by the manufacturer or discarded. The latter is frequently more practical.

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[5] *Op. cit.*, p. 7.

[6] *Amberlite Ion Exchange*. Philadelphia, Rohm & Haas Company (Sept., 1953), p. 7.

What Is Meant by Regeneration?

When an exchange bed becomes depleted it must be regenerated or discarded. The process of regeneration is simply an application of the Law of Mass Action. Obviously, ion exchange reactions are reversible; a dynamic equilibrium exists in the exchanger column with the degree of shift to the right or to the left (referring to the chemical equation representing the equilibrium) dependent primarily on the rate of flow. The faster the rate of flow—within practical limitations—the smaller will be the concentrations of the products. This causes the point of equilibrium to shift to the right during the run. Eventually however, the supply of reactant exchanger will reach a level of concentration low enough to cause the reaction to cease, signifying that the exchanger is in need of regeneration. Regeneration consists of shifting the point of equilibrium as far to the left as possible. This is accomplished by increasing the concentration of one of the products. This reverses the reaction, regenerating the exchange resin for another run. A given ion exchange resin may be regarded as a dispenser of that ion. When its supply is exhausted, the dispenser must be restocked with ions. The restocking of an ion exchange resin is called regeneration. Thus, to regenerate a hydrogen exchanger we must replenish the supply of hydrogen ion. HCl does this very satisfactorily:

$$CaR_2 + 2HCl \rightarrow 2HR + Ca^{++} + 2Cl^-$$

The calcium and chloride ions formed in the above regeneration are flushed out of the exchanger with running tap water.

The anion exchanger must be regenerated with a "base." Sodium carbonate is used, being sufficiently basic by hydrolysis:

$$R_2SO_4 + Na_2CO_3 + 2HOH \rightarrow 2ROH + 2Na^+ + SO_4^{--} + H_2O + CO_2$$

Flushing with tap water removes the sodium and sulfate ions as well as the carbon dioxide formed when the hydroxyl ion content of the anion exchange bed has been completely replenished.

What Ions Are Commonly Removed During Deionization?

The ions commonly removed during the deionization of typical tap water are:

Cations: Al^{+3}, Ca^{+2}, Fe^{+2}, Mg^{+2}, Mn^{+2}, K^+, and Na^+.
Anions: HCO_3^-, HPO_4^{--}, HSO_3^-, HS^-, CO_3^{--}, Cl^-, NO_3^-, SiO_3^{--}, and SO_4^{--}.

Is Deionization Equipment Available for High School Laboratories?

Several companies are manufacturing deionization units which are designed to meet the needs of small laboratories. Some of these com-

panies have several different models available. These models vary in applicability and in price.

The type best suited to small high school laboratory use is the cartridge type deionizer. This type of deionizer consists of a relatively inexpensive replaceable cartridge and a permanent bracket. The cartridge contains ion exchangers which change color when exhausted and operates on the mixed-bed (or mono-bed) principle.

At the end of this article is appended a bibliography and sources from which one may obtain additional information on deionization and deionization equipment. Applications of ion exchange are manifold; the purposes to which the principles of ion exchange have been applied are so extensive that no attempt will be made in this paper to enumerate them.

Summary

Deionization is rapidly replacing conventional distillation as a source of laboratory water. Pure water may be obtained readily and cheaply by use of ion exchangers. The mixed-bed method produces water quickly that is completely satisfactory for high school use. Inexpensive deionization equipment is being marketed for use in small laboratories.

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———. *Amberlite Monobed Deionization*, Rohm & Haas Company, The Resinous Products Division, Philadelphia, pp. 13, 1952.

Possible Sources of Additional Information:

While preparing this paper, the writer was supplied with considerable material by the following companies. He wishes to acknowledge this and to express his sincere appreciation for their help.

Illinois Water Treatment Company, 840 Cedar Street, Rockford, Illinois.
Rohm & Haas Company, The Resinous Products Division, Washington Square, Philadelphia 5, Pennsylvania.
The Dow Chemical Company, Midland, Michigan.
The Permutit Company, 330 West 42nd Street, New York 36, New York.

PROBLEM DEPARTMENT

CONDUCTED BY MARGARET F. WILLERDING
Harris Teachers College, St. Louis, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, Harris Teachers College, St. Louis, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solution should observe the following instructions.

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

In general when several solutions are correct, the ones submitted in the best form will be used.

2413. *Proposed by Julian H. Braun, Washington, D. C.*

Show that

$$\cos 15^\circ = 4 \cos 5^\circ \sin 25^\circ \sin 35^\circ$$

Solution by Cecil B. Read, University of Wichita, Wichita, Kansas

Using standard identities which express a product as a sum

$$\begin{aligned} 4 \cos 5^\circ \sin 25^\circ \sin 35^\circ &= 4 \cos 5^\circ \frac{(\cos 10^\circ - \cos 60^\circ)}{2} \\ &= 2 \cos 5^\circ \cos 10^\circ - 2 (\cos 5^\circ)(\tfrac{1}{2}) \\ &= \cos 15^\circ + \cos 5^\circ - \cos 5^\circ \\ &= \cos 15^\circ. \end{aligned}$$

Solutions were also offered by: Richard H. Bates, Milford, N. Y.; Walter T. Grant, Rutherford, N. J.; V. C. Bailey, Evansville, Ind.; John O. Chellevold,

Waverly, Iowa; Felix John, Eddington, Pa.; C. H. Butler, Kalamazoo, Mich.; Russell H. Godard, Corvallis, Ore.; C. W. Trigg, Los Angeles, Calif.; Leon Bankoff, Los Angeles, Calif.; A. R. Haynes, Tacoma, Wash.; Mart E. Mitchell, Plainfield, Ill.; and the proposer.

2414. *Proposed by Brother Felix John, Eddington, Pa.*

Solve the equations

$$(ax)^{\log a}=(by)^{\log b}$$

$$b^{\log x}=a^{\log y}.$$

Solution by the proposer

$$(ax)^{\log a}=(by)^{\log b} \tag{1}$$

$$b^{\log x}=a^{\log y}. \tag{2}$$

1. Let $\log a=m$ and $\log b=n$.

2. Write equations (1) and (2) in logarithmic form, making these substitutions:

$$m^2+n\log x=n^2+n\log y \tag{3}$$

$$m\log y=n\log x. \tag{4}$$

3. Solve equation (4) for $\log y$, substitute in equation (3), and solve for $\log x$:

$$\log x=\frac{m(n^2-m^2)}{m^2-n^2}=-m=-\log a.$$

4. Hence,

$$x=a^{-1}=\frac{1}{a}.$$

5. Substitute in equation (4):

$$\log y=-n=-\log b$$

$$\text{or}\quad y=b^{-1}=\frac{1}{b}.$$

This problem appears in Hall and Knight's *Higher Algebra* as exercise 127 (2), page 502.

2415. *Proposed by A. R. Haynes, Tacoma, Wash.*

The problem should have read:

Show that the square of the distance between the incenter and orthocenter of a triangle ABC is $2r^2-4R^2\cos A\cos B\cos C$, where r is the radius of the incircle and R is the radius of the circumcircle.

Solution by the proposer

Note: An equivalent form:

(a) $\overline{IH}^2=2r^2-2R\textcircled{R}$ where $\textcircled{R}$* is the in-radius of the pedal $\Delta H_1H_2H_3$ is used without proof by Johnson (Modern Geom., Houghton-Mifflin Co., 1929) on p. 205 in deriving the distance between the center of the 9-point $\odot$ and the in-center.

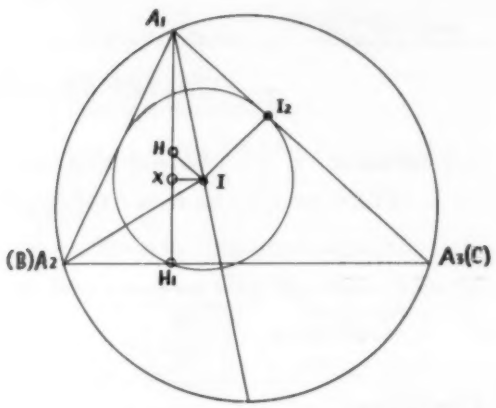
(b) The problem as stated is offered as Ex. 13, p. 247 of *Loney: Plane Trig.* (Cambridge University Press, 1895.)

See drawing on next page.

Formulae:

J—p. 163 (a) $A_1H=2R\cos A_1$ $HH_1=2R\cos A_2\cos A_3$

* Johnson, p. 191 gives $\textcircled{R}=2R\cos A\cos B\cos C$.



(b) $\cos A_1 \cdot \cos A_2 \cdot \text{Cos } A_3 = ®/2R$ where ® is radius of $\odot$ inscribed in pedal $\Delta H_1H_2H_3$

J—p. 191 (c) $\cos A_1+\cos A_2+\cos A_3=(R+\rho)/R$ where R is radius of circumcircle of ABC and ρ is radius of inscribed $\odot$ of ABC.

L—p. 137 (d) $\cos^2 A_1+\cos^2 A_2+\cos^2 A_3=1-2\cos A_1 \cos A_2 \cdot \cos A_3$

L—p. 235 (e) $r_1=S/(s-a)$ etc. where r_1 is radius of inscribed $\odot ABC$.

L—238 (f) $$\frac{1}{r_1^2}+\frac{1}{r_2^2}+\frac{1}{r_3^2}=\frac{a^2+b^2+c^2}{S^2}-\frac{1}{\rho^2}$$

(g) $a^2+b^2+c^2=2s^2-2\rho(4R+\rho)$ where $s=(a+b+c)/2$

L—238 derived from $\rho^2+r_1^2+r_2^2+r_3^2=16R^2-(a^2+b^2+c^2)$ using

A-C—p. 72 $r_1+r_2+r_3=4R+r$

L—p. 238 $r_2r_3+r_3r_1+r_1r_2=s^2$

L—p. 237 $r_1r_2r_3=S^2/\rho$

Ref. J: Johnson: *Modern Geom.*, Houghton Mifflin Co., 1929.
L: Loney: *Plane Trig.*, 1895, Cambridge U. Press.
A-C: Altshiller-Court: *College Geom.*

$\overline{IH}^2=2\rho^2-2R®$ Johnson p. 205 used without proof.

$\overline{IH}^2=2\rho^2-4R^2\cos A\cos B\cos C$ Loney p. 247 Ex. 13

Note: These are equivalent for $®=2R\cos A\cos B\cos C$*

Proof: Refer to Fig. & Formulae

$$\angle BAI=\angle\frac{A}{2}\quad \angle BAH=90-B$$

$$\angle HAI=\frac{A}{2}-(90-B)$$

$$=\frac{A-A-B-C+2B}{2}=\frac{B-C}{2}$$

$$\overline{IH}^2=\overline{A_1I}^2+\overline{A_1H}^2-2\overline{A_1I}\cdot\overline{A_1H}\cos\frac{B-C}{2} \tag{1}$$

$$\cos\frac{B-C}{2}=\frac{A_1X^2}{A_1I}$$

$$A_1I\cdot\cos\frac{B-C}{2}=A_1X$$

$$A_1X=\overline{A_1H_1}-\rho$$

$$A_1H_1=A_1H+HH_1$$

$$A_1X=A_1H+HH_1-\rho$$

$$\therefore \quad -2\overline{A_1H}\cdot\overline{A_1I}\cos\frac{B-C}{\angle} = -2A_1H(A_1H+HH_1-\rho)$$

$$= -2\overline{A_1H}^2-2\overline{A_1H}\cdot\overline{HH_1}+2\overline{AH}_1\rho$$

By (a)

$$A_1H = 2R\cos A; \qquad HH_1 = 2R\cos B\cos C.$$

$$= -2\overline{A_1H}^2-8R^2\cos A\cos B\cos CX4R\rho\cos A$$

Sub in (1)

$$\overline{IH}^2 = \overline{A_1I}^2-\overline{A_1H}^2-8R^2\underbrace{\cos A\cos B\cos C}_{\frac{\textcircled{R}}{2R}}+4R\rho\cos A.$$

$$-4R^2\cos^2 A$$

$$\overline{AI}^2 = \overline{A_1I_2}^2+\rho^2$$

$$\overline{A_1I}^2 = (s-a)$$

$$\overline{IH}^2 = \rho^2+(s-a)^2-4R^2\cos^2 A-4R\textcircled{R}+R\rho\cos A.$$

By cyclic transformation:

$$3\overline{IH}^2 = 3\rho^2+[(s-a)^2+(s-b)^2+(s-c)^2]-4R^2(\cos^2 A+\cos^2 B+\cos^2 C)$$
$$-12R\textcircled{R}+4R\rho(\cos A+\cos B+\cos C). \qquad (2)$$

Reductions:

$$(s-a)^2+(s-b)^2+(s-c)^2 = S^2\left(\frac{1}{r_1^2}+\frac{1}{r_2^2}+\frac{1}{r_3^2}\right)$$

$$\text{By (f)} = S^2\left(\frac{a^2+b^2+c^2}{S^2}-\frac{1}{\rho^2}\right)$$

$$= a^2+b^2+c^2-\left(\frac{S^2}{\rho^2}=s^2\right).$$

By (g)
$$s^2 = \frac{a^2+b^2+c^2}{2}+\rho(4R+\rho)$$

$$= \frac{a^2+b^2+c^2}{2}-4R\rho-\rho^2.$$

By Johnson p. 164:

$$4R^2\cos A\cos B\cos C = \overline{HA}_1\cdot\overline{HH_1} = \frac{a^2+b^2+c^2}{2}-4R^2 \quad \text{or}$$

$$\frac{a^2+b^2+c^2}{2} = 4R^2\cos A\cos B\cos C+4R^2$$

Substituting

$$(s-a)^2+(s-b)^2+(s-c)^2 = 4R^2\cos A\cos B\cos C+4R^2-4R\rho-\rho^2 \qquad (3)$$

By (b)
$$= \left(4R^2\cdot\frac{r}{R}=2Rr\right)+44R^2-4R\rho-\rho$$

2nd term of (2)

$$-4R^2(\cos^2 A+\cos^2 B+\cos^2 C) = -4R^2(1-2\cos A\cos B\cos C)$$

By (d)
$$= -4R^2+8R^2\cos A\cos B\cos C$$

$$+\left(8R^2\cdot\frac{\mathcal{R}}{R}=4R\mathcal{R}\right) \tag{4}$$

Right term

$$+4R\rho(\cos A+\cos B+\cos C)=$$

$$4R\rho\left(\frac{R+\rho}{R}\right)=+4R\rho+4\rho^2 \tag{5}$$

Sub. (3), (4) & (5) in (2)

$$\begin{aligned}3\overline{IH}^2=3\rho^2+\ & 2R\mathcal{R}+4R^2-4R\rho-\rho^2\\ &+4R\mathcal{R}-4R^2\\ &-12R\mathcal{R}\qquad +4R\rho+4\rho^2\\ \hline =6\rho^2-6R\mathcal{R}\ &\text{ or}\end{aligned}$$

$$\overline{IH}^2=2\rho^2-2R\mathcal{R}$$

Solutions were also offered by: Cecil B. Read, Wichita, Kans. and Leon Bankoff, Los Angeles, Calif.

2416. (*Misnumbered* **2516**) *Proposed by Martha Tobias, Springfield, Mo.*

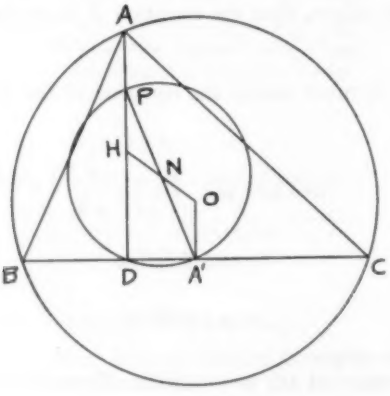
Given a vertex, the orthocenter and the nine-point center of a triangle, construct the triangle.

Solution by C. W. Trigg, Los Angeles City College

We utilize the following properties: 1) In a triangle the midpoints of the sides, the feet of the altitudes, and the midpoints of the segments joining the orthocenter to the vertices of the triangle, lie on the same circle. 2) The foot of an altitude to a side and the midpoint of the segment joining the orthocenter to the vertex opposite that side are the extremities of a diameter of the nine-point circle. 3) The center of the nine-point circle lies midway between the circumcenter and the orthocenter.

Construction: Denote the vertex, the orthocenter, and the nine-point center by A, H, and N, respectively. Bisect AH at P. With N as center and radius NP describe a circle cutting AH extended at D, and PN extended at A'. Extend HN to O so that $HN=NO$. With O as center and OA as radius describe a circle. Draw the line through DA' cutting the latter circle in B and C. (If D coincides with A', then draw the line perpendicular to DA at D.) BCA is the required triangle.

Solutions were also offered by: Walter T. Grant, Rutherford, N. J.; John Murphy; A. R. Haynes, Tacoma, Wash.; V. C. Bailey, Evansville, Ind.; Leon Bankoff; Los Angeles, Calif.; Richard H. Bates, Milford, N. Y., and the proposer.



2417. *Proposed by Robert Cawley, Dunmore, Pa.*

Solve the system for real values:

$$xy^2+xy^4=90$$
$$xy^5+xy^7=2430$$

Solution by C. W. Trigg, Los Angeles City College

Method I. Eliminating the constant terms, we have

$$27xy^2+27xy^4=xy^5+xy^7$$

or

$$xy^2(y^2+1)(y^3-27)=0.$$

Since only real finite values are sought,

$$y=3, \quad \text{whence} \quad x=1.$$

Method II. Solving each equation for x, we have

$$x=90/(y^2+y^4)=2430/(y^5+y^7),$$

so

$$y^2(y^2+1)(y^3-27)=0$$

Since only real finite values are sought,

$$y=3, \qquad x=1.$$

Method III. Dividing the second equation by the first, we have

$$y^3=27,$$

so

$$y=3, \quad \text{whence } x=1.$$

A solution was also offered by the proposer.

2418. *Proposed by Norman Anning, Alhambra, Calif.*

If an ellipse intersects its evolute at the ends of the minor axis, what is its eccentricity?

Solution by V. C. Bailey, Evansville College, Evansville, Ind.

Let

$$x^2/a^2+y^2/b^2=1$$

be the equation of the ellipse, then the equation of its evolute is

$$(ax)^{2/3}+(by)^{2/3}=(a^2-b^2)^{2/3}=(c^2)^{2/3}$$

Since the point $(0, b)$ must satisfy the equation of the evolute, we get the relationship, $b=c$.

Then

$$a^2=2c^2 \quad \text{and} \quad e=\frac{c}{a}=\frac{1}{\sqrt{2}}.$$

Second Solution

Let

$$x^2/a^2+y^2/b^2=1$$

be the equation of the ellipse.

The radius of curvature at any point of the ellipse is

$$R=\frac{(b^4x_1^2+a^4y_1^2)^{3/2}}{a^4b^4}.$$

The radius of curvature at the point $(0, b)$ must equal $2b$.
Then

$$R=2b=\frac{a^6b^3}{a^4b^4}=\frac{a^2}{b} \quad \text{or} \quad b^2=\frac{a^2}{2}.$$

Since

$$a^2=b^2+c^2,$$

we then have

$$e=\frac{c}{a}=\frac{1}{\sqrt{2}}.$$

Solutions were also offered by C. W. Trigg, Los Angeles, Calif.; John O. Chellevold, Waverly, Iowa; and A. R. Haynes, Tacoma, Wash.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.

PROBLEMS FOR SOLUTION

2437. *Proposed by C. W. Trigg, Los Angeles City College.*

Squares are constructed externally on the legs of a right triangle ABC. The joins of the vertices of the acute angles to the remote vertices of the squares on the opposite legs intersect in M, and cut AC and AB in B' and A' respectively. Show that:

1. The segment of either leg adjacent to the right angle is the mean proportional between the remote segments of the legs.
2. The product of the ratios into which M divides AA' and BB' is equal to the square of the sum of the legs divided by the product of the legs.
3. The areas of the triangles AMB' and $A'MB$ are in the same ratio as the cubes of the adjacent legs.

2438. *Proposed by Bro. Felix John, Philadelphia, Pa.*

Show that

$$x^6-x^5y+4x^4y^2-2x^3y^3+4x^2y^4-xy^5+x^6>0$$

for all real values of x and y. (From Chrystal's Algebra, V. II).

2439. *Proposed by Dewey C. Duncan, Los Angeles, Calif.*

If

$$x_1.\ x_2.\ \cdots\ x_n$$

are positive real numbers, not all being equal, then show

$$\frac{x_1+x_2+\cdots+x_n}{n}>\sqrt[n]{x_1x_2x_3\cdots x_n}$$

(a generalization of 2363).

2440. *Proposed by C. W. Trigg, Los Angeles, Calif.*

There are only two five-digit integers formed from two different digits whose squares minus one million are permutations of the ten digits.

2441. *Proposed by Nathan Altshiller-Court, University of Oklahoma, Norman Okla.*

The product of the powers of a vertex of a triangle with respect to the four tritangent circles is equal to the product of the squares of the radii of the four circles.

2442. *Proposed by V. C. Bailey, Evansville, Ind.*

Find an expression for the length of the line, parallel to the parallel sides and bisecting the area of a trapezoid, in terms of the parallel sides. One side of the trapezoid is perpendicular to the parallel sides.

BOOK REVIEWS

POWER OF WORDS, by Stuart Chase and Marian Tyler Chase. Cloth. 1954. xii+308 pages. 14.0×21.0 cm. Harcourt, Brace and Co., 383 Madison Ave., New York 17, N. Y. Price $3.95.

In 1938 Thurman Arnold said, "(Chase's) 'The Tyranny of Words' will be one of the most influential books of this decade." Now, almost a decade later, Chase's "Power of Words" attempts a more positive and inclusive appraisal. In this later volume the critic turns creative. He concludes his assessment with "Perhaps the next great revolution, following the industrial, will be the revolution in communication. This book is a small contribution to that end."

Two thirds of the pages are devoted to Part One on Findings. These sixteen chapters are addressed to: semantics, cybernetics, linguistics, brain physiology, group dynamics, communication among animals, perception experiments, and language development in children.

Part Two is labelled Applications. In this comes the specific relevance of it all. For the writer at his desk, the economist before his audience, the doctor at the bedside, the teacher in the classroom, the diplomats around the conference table or the bureaucrat enmeshed in gobbledygook he proposes remedial therapy.

In a manner that his readers have come to expect author Chase follows his own prescription and does not "mistake the map for the terrain," makes generous use of explicit referents and refrains from "churning the verbal ocean" with semantic explosives. There are paragraphs where he "digs so deep" that this reader found the going difficult. Those were few, however, and are generally clarified by a second or third reading.

Some especially stimulating sections had to do with "words as a sort of cultural cement" that bind communities together and language stressed as one of the limiting elements in a culture's attempt to arrive at what might be called a "world view." There are some elements of another language that are not translatable into English, for instance. For some readers the idea that we are often unable to think because we don't have the words for the ideas may be a surprise.

Teachers of science will find stimulus in "the revolution in communication brought by relativity"; in "rules of talk in face to face groups" and "learning to listen." They will also profit by the chapters on "Tools for writers," "Gobbledygook" and "Schoolroom talk." No one should put the book aside until he has read the concluding chapter on "The unused potential." This is not only a book to be read but one to be used. It should be a companion volume with the dictionary upon the desk of every active teacher or school administrator.

B. CLIFFORD HENDRICKS
Longview, Wash.

PHYSICS, THE STORY OF ENERGY, by H. Emmett Brown, *Professor of Science, New York State College for Teachers, Buffalo, New York;* Edward C. Schwacht-

gen, *Science Consultant, Division of Curriculum Development, Chicago Public Schools, Assistant Principal, Wells Evening High School.* Cloth. Pages xi+596. 17×23 cm. 1954. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $3.80.

This is the second edition of this physics text. To those familiar with the book, there are few fundamental changes. It has been brought up to date on topics such as 3D, atomic energy uses, and television. Many of the illustrations have been changed.

To those not familiar with the text, it is an outstanding text for the physics class having many superior students. The material is presented in a more advanced form. It introduces the use of trigonometric functions, so essential for anyone going on to college science. The book is also different in its order of presentation. The topics are sound, light, mechanics, electricity, motion, and heat, in that order.

Each chapter has a summary, questions, problems, and references for further reading. Another feature is the "Things to Do," section. This contains many excellent suggestions for projects, not only for the chapter, but for outside projects for the Science Talent Search and for use in Science Fairs.

E. Wayne Gross
Bloomington, Ind.

New Senior Science, by George L. Bush and Will S. Thompson, *Department of Chemistry and General Physical Science, Kent State University, Kent, Ohio.* Cloth. Pages ix+642. 17×23½ cm. 1954. American Book Co., New York. Price $4.28.

Practically every teacher who has had the experience of teaching a physical science course has felt the need for a good text. It must be: not too difficult, yet contain some real science materials. It must contain many practical everyday applications, and have many experiments which can be done in the average laboratory or classroom. *New Senior Science* has been written to meet these needs.

With all due respect to former editions of *Senior Science*, they did not meet these needs. *New Senior Science* has been completely revised and rewritten. The format, printing, and illustrations make this an outstanding text. The style of writing permits great flexibility as to its use. For example, the chapter on chemistry is written so it can fit the needs of any class or individual. If chemistry fundamentals are not desired, that material can be omitted and the many practical applications discussed. However, for the better students, this chapter includes materials on elements, compounds, mixtures, atomic structure and equations. These give him valuable background for either high school or college chemistry. Other units are similarly written.

This text also includes units on "soil conservation, selecting and operating a home, problems of safe living, and problems of healthful living." The last mentioned unit doesn't duplicate matter from the usual biology course. Each of the 12 units ends with a summary, questions, projects and experiments for individuals or a small group, and additional reading references.

E. Wayne Gross
University School
Bloomington, Indiana

Laboratory Practice of Organic Chemistry, Third Edition, by G. Ross Robertson, *Professor of Chemistry at the University of California, Los Angeles.* Cloth. Pages x+377. 13.5×21 cm. 1954. The Macmillan Company, 60 Fifth Avenue, New York 11, N. Y. Price $4.00.

Part I of this manual includes a splendid treatment of the principles of laboratory techniques. The explanations of these principles are brief, but sufficiently understandable. Good basic chemical theories are well placed and many provocative questions and problems help the student to master the foundational subject matter.

Part II is devoted to laboratory experiments which are correlated with the principles treated in Part I. There is a well distributed range of manipulations of apparatus and of type procedures. Uncommon to many elementary organic chemical manuals is the inclusion of library problems of syntheses which the reviewer feels is most desirable.

This manual is not the fill-in type nor does it contain work sheets.

ROBERT J. ELDRIDGE
Western Michigan College
Kalamazoo, Michigan

MINNESOTA'S ROCKS AND WATERS, A GEOLOGICAL STORY, by George M. Schwartz, *Director of the Minnesota Geological Survey*, and George A. Thiel, *Chairman of the University Geology Department, Minneapolis, Minnesota*. Cloth. Pages xviii+366. 15×23.5 cm. 1954. University of Minnesota Press, Minneapolis 14, Minn. Price $4.00.

This is a book for the amateur, the tourist, the rock-hunter. It interprets the story of the varied landscape, the Land of Lakes, the hills, rivers, prairies, and fertile farm lands. The story goes back to some of the oldest exposed rocks to be found anywhere in the world and to some of the newest deposits left by the retreating glaciers only about 11,000 years ago. Minnesota is a country that offers a wonderful laboratory for the study of all ages of the earth from the oldest to the present action of wind swept dunes and recently drained lake plains.

The book is in two sections. The first, consisting of nine short chapters, describes the land as it can be seen, either by excursions or by arm chair entertainment. Here one finds the description of lakes, rivers, and land forms; the span of geological time shown by the chert and jasper of the Keewatin formations of the Archeozoic Era down through many of the intermediate forms to the present deposits of gravels, sands, and clays. This gives the groundwork for understanding and enjoying the excursions through the various sections of the state under the direction and guidance of the authors. For this the state is divided into six sections, each with its different characteristics, interesting sights, and geological products. A few pages of reference material giving a list of the minerals, the publications of the Minnesota Geological Survey, and a glossary, complete the book.

If you are a resident of Minnesota you cannot afford to miss this book. If you live outside the state and plan a trip there you will need it. If you cannot go there the book will help you to see much of the state from your own home wherever you live. Congratulations to you, Professors Schwartz and Thiel. This book will do much to promote the study that is so often neglected in our schools.

G. W. W.

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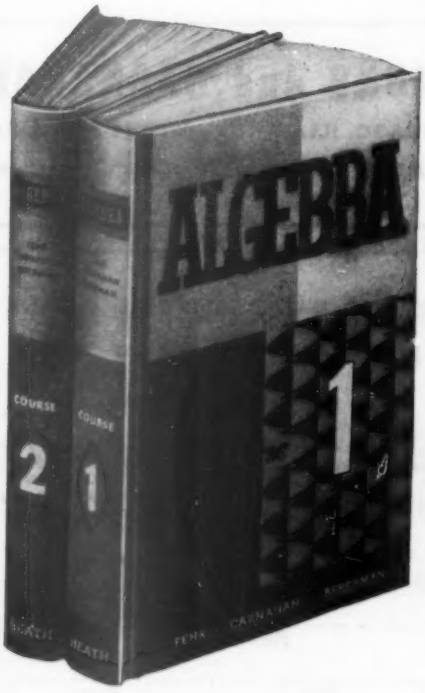

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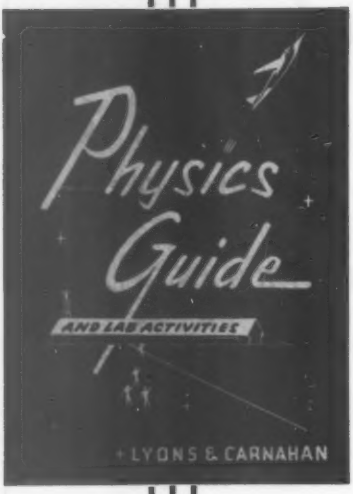

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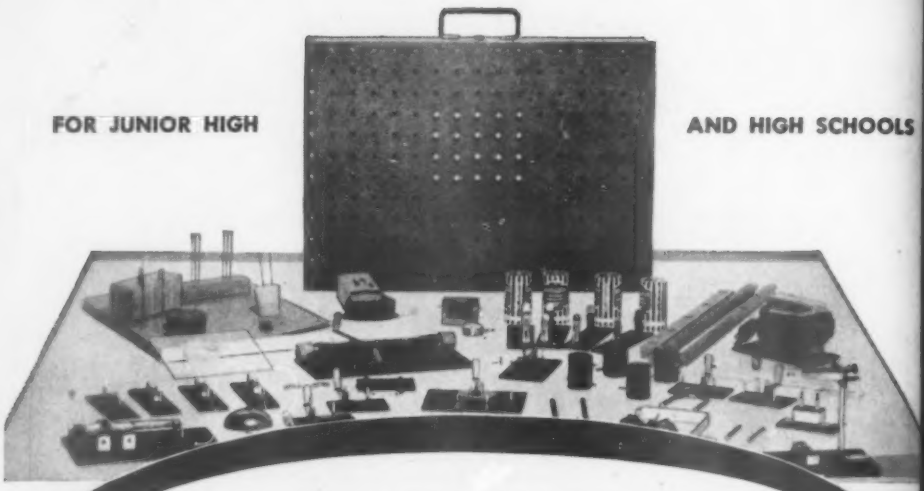

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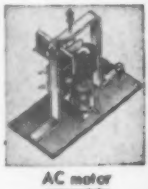

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